REHABILITATION AND PRESERVATION INSPECTORS' MANUAL

Southern Building Code Congress International

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Rehabilitation and Preservation Inspectors' Manual

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PREFACE

There are many excellent books which deal with building inspection and diagnosis. In recent years there has been a new interest in older buildings and their rehabilitation and re-use. In developing plans for a program which would train building tradesmen in the areas of new construction and in renovation/preservation of older buildings, we found that knowledge of building inspection was a vital area. Also, we found that building codes sometimes worked against the renovation of older buildings.

In order to understand the building inspection area better we contacted building code inspection officials. Through this contact we learned that the Southern Building Code Congress International (S.B.C.C.I.) was working on a manual for rehabilitation and preservation inspection, which demonstrates how important the rehabilitation market has become. We entered into a co-sponsored project with S.B.C.C.I. and have edited their work into a format for use by our students.

The purpose of this text is to provide students with a basic understanding of the building code and inspection techniques for older buildings.

The project was funded by the Mary Reynolds Babcock Foundation. Their generous support and gracious understanding of the complex and time-consuming nature of an in-house project has carried us over many trying times. The project was conceived by John Crumpton, former President of Durham Technical Institute, and further supported by Phail Wynn, Jr., current President. Murial Plank re-drew, traced, lettered and contributed original drawings, including the one on the cover. To those people we extend our sincere thanks.

Durham, N.C.
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TABLE OF CONTENTS

Page

CHAPTER I: The Rehabilitation Process 1

CHAPTER II: Fundamentals 11

CHAPTER III: Structural Systems 35

CHAPTER IV: Equipment Systems 79

CHAPTER V: Safety / Protection Systems 131

CHAPTER I
THE REHABILITATION PROCESS

GENERAL

The rehabilitation of an existing building involves a process of many steps, whose specific nature varies depending on the intent of the initiator of a project. Rehabilitation may be primarily concerned with either adaptive re-use of the building or its preservation, with the initiator being an individual or organization concerned only with that one building. It may, on the other hand, be part of a community development program concerned with maintaining an adequate stock of adequate housing for the residents of the community. While the steps through which a project moves are similar for building or housing rehabilitation, the procedures and techniques used vary considerably for surveys, plans, feasibility studies, design and construction documents, and code enforcement.

BASES FOR CODE PROVISIONS

Regardless of the basis for initiating a rehabilitation project, the concern of all involved should be to provide at least minimum conditions in the resulting building. Over the years, building codes have been concerned with those factors of a building related to safety, health, and welfare. In most cases, code provisions have become more stringent as unfortunate occurances or changing social conditions indicated a need for greater protection either to the occupants of a building or to the neighboring buildings.

Although the term "building code" normally refers only to the document regulating the general construction of a building, in this manual, "building code" or "codes" also includes the other codes (plumbing, mechanical, gas, and electrical) which deal with the total building, and also two other codes having specific reference to the use of existing buildings (fire prevention and housing).

In the United States, concern for fire safety has been evident almost from the beginning, as evidenced in the building code for Salem, North Carolina of 1788.

> *It is important that the necessary fire-proofing be provided and we emphasize that it is basic that there be a separation of fireplaces and compustible material, particularly where heat is intense and sparks are leaping around . . . should be covered with roof tiles instead of shingles and fuel sheds should be at a distance because sparks are always flying . . . We think that it is evident that no wooden chimneys be built here. However for fire prevention . . .*
>
> *(a) Chimneys should have good foundations and not just be placed on logs; be well bonded and be built of brick at least four inches thick; be parged inside and out; rise to a*

sufficient height above the roof; have no seams too close to them in such a way that the heavy load on them will cause the chimney to crack and settle as can happen easily in flues.

Many buildings essentially the same as those now considered worthy and necessary for preservation have been lost due to fire. In many cases, loss of life also occurred, since so many buildings are used for purposes which involve many occupants unfamiliar with the means of getting out of the building in event of fire.

Closely related to fire safety are code provisions concerning adequate strength of the structural members to preclude collapse or sagging. This concern far antedates even fire-safety, since the code of Hammurabi (3000 BC) provided for the death of the builder if a building collapsed and killed the owner.

If a builder build a house for a man and complete it, that man shall pay him two shekels of silver per sar (approximately 12 square feet) of house as his wage.

If a builder has built a house for a man and his work is not strong, and if the house he has built falls in and kills the house-holder, that builder shall be slain.

If the child of the householder be killed, the child of that builder shall be slain.

If goods have been destroyed, he shall replace all that has been destroyed, and because the house was not made strong, and it has fallen in, he shall restore the fallen house out of his own material.

If a builder has built a house for a man, and his work is not done properly and a wall shifts, then that builder shall make that wall good with his own silver.

Early prescriptive codes in the United States included specific detailed requirements; modern performance codes generally reference the same engineering standards and procedures used by structural engineers for design. This development occurred due to the greater wealth of alternative needs and materials of construction, and to ever-increasing knowledge of structural performance.

Similarly, for those components whose continuing function is critical, codes have provisions for durability. Preventing conditions which generally lead to decay or destruction, for example, is the basis of provisions for wood covering proximity to earth, of requiring either termite protection or the use of resistant-species, and for painting of exterior surfaces.

Provisions for health in the codes are concerned with water, light, ventilation, and sanitation. The means utilized for distribution and use of water, and removal of related waste were regulated due to the intent of communities to prevent loss of life resulting from the spread of infection. Congestion resulting from the rapid influx of immigrants during the nineteenth-century generated the need for those provisions of the codes requiring minimums of light, fresh air, and area per occupant. As cities became more populous and more complex, other provisions were added to control the accumulation of waste and trash, and to limit the access of rats or other vermin and insects into buildings to reduce the spread of infectious diseases.

Other problems have generated code provisions. An isolated building with no close structures creates no problems for adjacent structures, but with the close proximity necessary under the conditions in cities, the codes include protection for nearby buildings. The concerns of society to allow all citizens to use the resources of the community equally introduced code provisions for access to buildings by handicapped persons (although no such pressures have developed widely yet to provide exits for the handicapped in the event of emergency). In recent years, due to the energy crisis, additional provisions have been added to reduce the amount of energy required to provide adequate comfort, and with increasing interest in the use of non-depletable energy sources, code provisions for the use of solar energy are being developed.

Unfortunately, in the United States, most social responses to problems result not from an intelligent scanning of potential hazards but rather as a response to crisis, a response only following catastrophe, when conditions have reached a critical level of dissatisfaction, and rapid action is demanded. The function of code enforcement has been to prevent further development of those conditions which have led to these serious conditions, by requiring the construction of new buildings to meet certain criteria. The problem in rehabilitation construction is to remove these conditions in existing buildings, and at the same time prevent further loss of existing buildings which provide links to the past.

REHABILITATION AND PRESERVATION

Surveys

Planning for rehabilitation begins with a survey to identify and evaluate a community or area's resources. Not just major landmarks but every physical resource and every characteristic in the designated survey area needs to be identified—from the best to the worst of the old and new, from buildings to street furniture, landscaping, open spaces, views and vistas. A clear picture of a community's character and physical growth emerges from a comprehensive survey, a picture that can help guide future development in protecting the good and avoiding the horrors of the past or present.

Preservation surveys have numerous goals and results: they identify structures and sites that meet criteria for listing in national, state or local landmarks registers, and thus become eligible for whatever protection is available; they define areas to be designated as historical districts; they provide the impetus for creation of preservation agencies and private groups; they sensitize residents to their community's value. Above all, preservation surveys are a tool for comprehensive planning, identifying elements that not only are as integral to a community's development as the provisions for education, health, safety, housing, transportation, business, and recreation more routinely studied by urban and regional planners, but that, in fact, have the potential to serve all these needs.

If inventoried properties and areas are seen only as isolated objects, the survey becomes little more than a guidebook to what is there (and what may be gone tomorrow). But if they are regarded as useful components that give a place its unique character, they can be cornerstones of all future development—comprehensive blueprints for living environments fo quality, ways of guiding new development in such a way as to be compatible with, and actually enhance, the historic and architectural qualities.

A survey usually refers to the actual gathering of historical physical data and illustrations through research and field work, while the inventory is a selective list from the survey of sites or amenities professionally evaluated for their retention value or need for protection.

There are as many kinds of surveys as there are specific reasons for carrying them out. A survey can be limited to a carefully defined geographic area such as a neighborhood or conclave of buildings, or it can encompass the nation or an entire state or community. It can be limited to places of obvious cultural significance, or certain individual building types such as industrial or commercial structures, or it can cover all built and natural resources. The amount of information about individual structures that a survey provides also varies. On the one hand it may only suggest the rudiments such as construction dates and architectural style, or it may provide an in-depth analysis of an individual structure, including measured drawings, photographs, chain-of-title information, and other historical data and technical architectural descriptions. The most far-reaching surveys also include the area's social and economic factors, development patterns, visual relationships, and design elements.

The scope of some surveys is determined by their intended use, or the organizer's preservations goals—whether to locate properties for nomination to national or local landmarks registers, to gather data to aid local planners, to stimulate public awareness, to create the basis for community-action programs to improve neighborhoods, or to guide property owners in their rehabilitation.

A survey produces a wealth of material—historical data, development statistics, photographs, drawings, maps. As many preservation agencies and organizations have discovered, unless these are translated into a program of action, the survey remains little more than an academic exercise, a picture of a neighborhood or community at a point in time, static as a photograph, not a comprehensive plan where it can have a positive effect.

Plans

Preservation plans range from general documents that are essentially site surveys or inventories with identifed goals, to urban design plans for historic areas, and comprehensive master plans in which preservation or conservation of existing resources is only one element, although a vital one, among a range of social and environmental goals. Despite their variations in form, common factors characterize plans for preservation: a history of the surveyed area's growth and a general description of the population, land use, and building types and conditions; the surveyed physical resources, often ranked or grouped by priorities, usually form the nucleus. What sets a plan apart from a survey is a statement of goals and techniques to implement them. Goals can be as limited as maintaining the architectural or physical integrity of significant individual structures or as broad as protecting whole enclaves or even maintaining and enhancing the overall environmental amenities and social character of the area. But the plan should not only identify the important elements of the environment, but also assess how the desires of people to conserve and improve the livability of their neighborhoods can be accomplished.

Usually a plan is only that: a suggested means of achieving a specific goal. As such it is constantly subject to change and updating, as attitudes and conditions change and new techniques are developed.

A planning program is only as good as the concrete results it achieves in the improvement of the physical and social subjects it studies . . . without implementation, the planning program is time, money, energy, and ideas wasted.

Buildings are still around to be used for some purpose, and that is the point of adaptive use—bringing them back to life.

In the United States, what once seemed an endless supply of land and other resources discouraged any sustained interest in adapting old but sound structures for contemporary needs. Conscious application of this technique was limited to a handful of architects and decision makers, to admirers of aging architectural gems, and to the poor, who adapted from necessity. Since the late 1960s, however, economic and social forces have made adaptive use of existing structures an increasingly promising alternative to new construction.

Rehabilitation is now commonly being viewed as a means of renewing cities through intelligent reuse of existing resources. It is difficult if not impossible to define one process or formula for finding new lives for old buildings. It is a creative act, calling for the ingenuity, determination, and sensitivity of a matchmaker. The process is just that: matching today's needs to yesterday's resources. Adaptive use need not be limited to the adaptation of architecturally or historically significant buildings. It can take as many forms as it has names. A building also can be adapted to contemporary requirements and continue to serve in the same way it always did. The nineteenth-century church that has been abandoned by one congregation may easily continue in the same use by another, making room for twentieth-century requirements such a indoor restrooms, fire exits, and other safety measures. Houses can still be houses. Adaptive use means simply that buildings are modified to some degree to meet contemporary demands.

Old buildings have become all sorts of things. Factories are being developed as shopping centers as well as apartments; an icehouse has been converted to offices, schools to housing, a parking garage to a movie theater, churches to restaurants.

Feasibility

In order for a specific project to be implemented, feasibility studies need to be developed; firstly, to determine the specific use-needs which can be met in the building; secondly, whether the project is economically feasible in terms of being marketable and in terms of the probable cost/revenue ratios; and thirdly, whether each of the possible specific uses is viable in terms of reasonably being within code limitations.

Obviously included in the feasibility studies should be consideration of the various tax credit and/or tax-incentive programs of the federal, state, and local governments for rehabilitation and preservation projects. Several of these approaches are premised on the building being a part of an historic district or being itself listed in the National Register, either of which can be the result of the survey. This status is also critical later in terms of determining compliance with the code.

In these initial studies, great imagination and vision are highly desirable attributes in the participants, since a routine, pedestrian approach may well produce misleading information. The essential questions are "What can be done?", "How can it be done?", and "Can it be done?".

Design

In the design phase, once a specific use-package has been developed, the architect and engineers, and the code enforcement personnel should utilize creativity and imagination together with great attention to detail. A fundamental necessity involving both the design team and the developer-team is the development of a comprehensive program. Not only will it serve the design team as the basis of developing the plans and specifications, but it will also provide the code enforcement official with a better understanding of the aims and intent of the project and will enable him to also share in the development of a worthy "addition" to the community's resources.

Obviously part of this program, for example, should be clear identification of those features or details which should be preserved. However, a good program will also provide the basis for balancing various aspects of development, a necessity in rehabilitation work which may change as additional information as to conditions becomes available during construction.

CHARACTER

In each community, some of the buildings of its past are so clearly and definitely to be preserved that only the means of doing so is in question. Many others have no such overwhelming claim yet present justifiable reasons. Part of this justification may lie in their character, the overall effect of a building. Elements of a building which may contribute to its character include scale, proportion, massing, height, shape and floor plan, roof lines, types of construction materials and finishes, textures, color, porches and entrances, columns, towers, chimneys, windows and doors, moldings around doors and windows, cornices, decorations, even landscaping. Interior clues are found in wainscoting and panelling, flooring, color, decorative elements, moldings, mantels, doors, stair balustrades. Construction methods—bonding of brick, use of timber or steel frames, joining of logs—are other guides.

Construction

During construction, everyone working on an existing building should be prepared for surprises. Some times these surprises are pleasant, such as finding covered-over architectural details, but more often they are problems. Everyone knows the cliche, "They just don't build them like they used to." They certainly don't. When problems arise, the inspector will probably be the first building department representative to evaluate the situation. If the unexpected conditions involve structural members, a competent determination of safety must be made immediately. New structural details may be required. Since deterioration often takes place in covered-over areas, unexpected dry rot and termites may be discovered when members in these areas are revealed. Other problems which may arise involve defective wiring, plumbing, and heating.

When pleasant surprises occur, the owner should be encouraged to recognize their value and take advantage of them, even if this means modifying his plans.

HOUSING MAINTENANCE AND REHABILATION

Surveys

Maintenance surveys involve systematic cellar-to-roof, house-to-house, block-to-block inspection of all properties within the specific area and include all the followup work required to bring the substandard housing up to code standards within a reasonable period. By putting major emphasis on this type effort instead of on the complaint-oriented approach, blight is checked and an overall upgrading of residential sections is achieved in one portion of a community after another. Thus, systematic area inspection is both a longer lasting and a much more effective method of improving housing and stablizing property values than the traditional complaint method. Whether this consists of so many blocks, an entire neighborhood, or a section thereof, it should be of such size as to permit the local code enforcement team to inspect and systematically effect minimum housing standards within a manageable time.

Usually a municipality combines its area work with some complaint and referral inspections. This is not objectionable as long as major emphasis is given to the area programs, and the inspectors move through the various sections of town systematically. Only in this way can a community's housing inspection program contribute adequately to the municipal efforts to upgrade all substandard housing and stem the deterioration of individual homes and neighborhoods. A percentage of inspection force should, however, be primarily assigned to complaint and referral work so that prompt action can be taken on all cases in which the problems are too severe to await actions in connection with the area inspections.

While the area-wide or neighborhood inspections will correct violations of the housing code, this is all they will accomplish. Once these neighborhoods are brought up to standard, inspectors will move on to other neighborhoods, but will be forced to return at a later time and repeat the process.

If a neighborhood has declined to the extent that there is a large amount of housing violations, then it is obvious that something or someone or both have caused the neighborhood to deteriorate. Any effort that does not also eliminate the cause for deterioration can only be a token effort and frequently a wasted effort. Unless a housing program evaluates the total neighborhood for both housing violations and for environmental stresses within the neighborhood that may have caused the deterioration of the housing, then the inspection has not been complete.

What then are these "environmental stresses"? Environmental stresses are the elements within a neighborhood that influence the physical, mental, and emotional well-being of the occupants. They include items such as noise, glare, excessive traffic problems. If a housing program is to be complete, these stresses must be identified and assessed. Efforts must then be made in conjunction with other departments within the city to program capital improvement budgets to alleviate or minimize these stresses.

In some communities the housing inspectors are expected to center their efforts primarily on complaint and referral inspections. This approach satisfies the persons making the complaints and referrals, and helps improve some of the municipality's substandard housing. However, it does little to bring about general improvements in any section of the community and actually constitutes an inefficient way of using the available inspection manpower because the men have to spend so much time traveling from one area to another.

Many supervisors and inspectors realize this unsystematic method not only wastes time but also is an ineffective way of upgrading housing and curing blight. First, on complaint inspections, the inspectors are usually instructed to confine their investigations to the dwelling unit specifically involved, unless the general conditions are so bad that an inspection of the entire building is deemed necessary. This means most complaint inspections are piecemeal, and do not ordinarily bring entire dwellings up to code standards. Second, even though numerous complaints are unwarranted, inspectors are often given so many to check each day that they do not have time to inspect other obviously substandard houses in vicinity of those complained about. Consequently, these "rotten apples" are left to spoil in the block, while the house that has been improved stands alone.

These two types of inspection are the field involvement of the housing inspector. He must inspect not only the houses for violations, but also the neighborhoods for environmental stresses. This will provide him with knowledge of physical conditions within the neighborhood. As mentioned previously, however, this is not the whole problem in most neighborhoods. Generally, the very difficult problem of the human element is involved. Many buildings and neighborhoods deteriorate because of apathy on the part of the neighborhood inhabitants. Efforts must be made to motivate them to work toward a better living environment. Experience by the Public Health Service (PHS) in motivational training has shown it to be very effective in raising the living standards of neighborhood populations.

In summary then, a housing inspection effort should be made up of three parts: First, a neighborhood or areawide housing inspection procedure; second, a neighborhood analysis procedure to identify, assess, and eventually control environmental stresses; and third, a program of motivational training for slum dwellers to raise the living standards of the neighborhood.

Plans

Following a housing inspection, if code violations have been found, steps must be taken to correct the conditions. In many cases, the owner has the responsibility for the correction, and he determines the details. In other cases, the community may assume part or all of the responsibility through a community development program.

If property is being improved through community action, the agencies having that responsibility generally develop a policy of the standard to which rehabilitation will work. As a minimum, violations of the housing or property maintenance code should be removed. In addition, those conditions that contain incipient damage which if not corrected will develop into problems even though they are not currently deleterious are often allowable items.

Design

It is unusual that professional assistance is available for housing rehabilitation. In lieu of architectural plans and specifications, the work to be included in the rehabilitation is described in a "write-up", a written description accompanied by technical specifications.

Feasibility

On the basis of the "write-up", a preliminary cost estimate can be developed to be used for comparison with both the cost of replacing the structure and with the available funds. If acceptable, the project can then be put out for bids.

Construction

Frequently, the community development agency handles the details of bidding, contracting, and inspection during construction, for the owner of the property. Since the initial inspections presumably detected the code violations, inspection during construction is more concerned with determining that the work performed is in accordance with the contract documents (the "write-up" and the specifications) and complies with code provisions, and should be concerned with the interest of the owner and the contractor.

CHAPTER II
FUNDAMENTALS

BUILDING TERMINOLOGY

In order to discuss the problems involved in the inspection of an existing building, the terms used in construction for the different components of a building must be known. In some cases, other terms may be used in different sections of the country; however, the terms used here are in most common usage.

STRUCTURAL CONCEPTS

General

Buildings are composed primarily of two systems: equipment; with the function of modulating the characteristics of the natural environment; and structure, with the functions of enclosing, supporting, and protecting the environments so created.

Current technology frequently separates the support function from the enclosing and protecting functions. However, in many older building and smaller buildings today, the three functions generally remain combined. In either case, the enclosing/protecting functions resist chemical and physical attack, while the support function resists the forces of gravity, wind, snow, earthqakes, etc.

Whether separated or combined, the support function is subjected to two sets of forces, vertical and horizontal. Floors provide not only the horizontal surfaces on which the uses of the building occur, but also the means of transferring the loads of the occupants, equipment, and goods, and the weight of the floor structure to the vertical support elements. The horizontal structure elements also resist the horizontal forces of wind and earthquakes.

The vertical support elements not only transfer to the ground these forces or loads, but also the weight and wind loads of the walls, and the loads of wind, snow, and equipment from the roof. The support elements absorb these forces and resolve them into stress patterns in transferring the force to the ground.

Patterns of Stress

Stress patterns termed "normal" include tension, compression, and bending; while those termed "tangent" include shear and torsion.

In a simple beam (Figure 2-1a), supported at each end with a uniform loading, the beam will tend to bend as shown in Figure 2-1b. The fibers in the upper portion of the beam are subject to compressive stress, since this part tends to being shortened. The fibers in the lower portion tend to being lengthened, and are subject to tensile stress. If the strength of the fibers is higher than these stresses, the beam is structurally safe. However, the amount of bending (deflection) may be greater than the ceiling materials under the beam can accept, and the ceiling may crack; in addition, the bending stress may be higher than the bending strength of the materials of the beam (elastic limit) and the beam will remain deformed and will not return to its original shape.

If the tensile and compressive stresses are too great, there is also a tendency within the beam to shear horizontally (Figure 2-1c) since these stresses are opposite.

In addition, the load of the beam (composed of the loads on the beam plus the weight of the beam) must be supported by the vertical support elements. There is, therefore, a vertical stress upward at each point of support equal to the vertical stress downward at that point, and these two opposite vertical stresses may cause the beam to shear (Figure 2-1d) if the loads are greater than the shear strength of the material.

Columns similarly may be subject to these stresses, depending on the manner in which the loads occur. An interior column, with loads coming from each direction (Figure 2-2a) is primarily subject only to axial or compressive stress; if, however, it is an exterior column, with loads primarily coming from one direction, (Figure 2-2b) it will be subject to both tensile and compressive stresses.

An arch (Figure 2-3a) is a form of construction in which a number of units span an opening by transferring vertical loads sideways to adjacent units and then to the supports, rather than a single unit spanning the opening as in a beam. Essentially, an arch is a curved beam in which wedge-shaped units of masonry are laid so that the vertical load forces the blocks together. Restrained from moving sideways by supports at each end, the arch permits spanning an opening with units which are too small individually to span it. If extended, the arch becomes a "vault" (Figure 2-3b); if rotated, it becomes a dome (Figure 2-3c).

Similarly, the truss is a structural unit (Figure 2-4a) combining small members (chords and web members) into a rigid framework, usually in a triangular pattern. Again members too small to span an opening individually are used together to provide the structural characteristics required. A three-dimensional truss is known as a space-frame (Figure 2-4b)

The stresses in beams are found in any horizontal support element: beams, joists, girders, slabs, or the chords in a truss. Similarly, vertical support elements include not only columns, but also posts, piers, or walls, or the web members of the truss.

Every material has certain characteristics of strength to resist these stresses, and each support element must be of such shape, area, and material to adequately resist the stresses developed in its use. In new construction, the strength-characteristics of a support element are readily determined. For existing buidings, however, while the shape and size generally may be determined by examination, the specific nature of the material used is unknown, both as to what was originally installed and also as to its present condition as a result of loading, temperature, and humidity conditions, during its existence. Furthermore, the structural members may have been weakened by the addition of plumbing or electrical systems if holes were drilled or notched improperly. (Figure 2-5).

Loads

The simplest loads to ascertain comprise the dead load, the sum of the weight of all materials used in the building. Appendices in the code normally provide one source of data concerning weights of materials and assemblies to be used in calculating dead load.

Codes also provide the bases for determining the live loads. First are the loads due to the occupants, furniture, equipment, and stored materials or goods, which will vary in actual practice fom one building to another. Each model code provides a tabulation of live loads (Table 2-1) to be used as a minimum, based on the normal quantity and weights found in each occupancy or specific area. If greater loads are known to be used, higher values should be used.

The second group of live loads are those resulting from normal and frequent weather conditions such as wind and precipitation (rain and snow), whose magnitude is established by code procedures based upon historical data and by the shape and position of the surface involved.

A third group of live loads is constituted by those forces, such as earthquake, hurricane or tornado, and flood, whose occurence is generally infrequent and sporadic but of great magnitude when they do occur. Certain locations are more prone to each of these and the code contains special provisions which may be adopted for use where needed, as in seismic, hurricane, or flood zones.

CONSTRUCTIONS TYPES

Building codes classify different structural systems on the basis of the degree of protection provided against fire-hazard, which varies according to the combustibility of the materials, the fire-resistiveness of the construction, and its location on the property. Depending on the occupancy-use of the building, the area per floor and the number of stories are limited to provide adequate fire-safety for the occupants of the building. The contents of a building contribute fuel for a fire, but since this will vary in quantity, the normal probable quantity has been assumed in the determination of the fire-hazard of each occupancy-type. The designation for each of these types is different for each of the model codes.

Types 1 and 2 construction are fire-resistant with all structural members made entirely of non-combustible materials. These two types afford fire-resistance and provide the greatest degree of fire safety of all the types. The two types vary only in the degree of fire-resistance provided, Type 2 being slightly lower. (See Figure 2-6)

The materials usually used with Types 1 and 2 are reinforced concrete protected structural steel for columns, beams and girders; concrete deck for floor and roof-slabs;

and non-combustible materials for exterior and interior walls and partitions, and ceilings. All of these materials must have a fire-resistant rating at least equivalent to that provided in the code (Table 2-2). Under some circumstances, the required rating can be reduced by one-hour if an automatic sprinkler system is included in the plans. The major deterrent to the use of Types 1 and 2 construction is that of cost, which may be offset to some extent by lower insurance rates, and by the greater area/floor and height permitted, which in turn might require less land acquisition.

Types 3, 4 and 5 construction have exterior walls of non-combustible materials, but the nature of the materials used in the structural elements varies with each.

Type 3 is heavy timber framing, with the required fire-resistance attained by the sizes of the structural members (whether sawn solid or glued-laminated), and by the avoidance of concealed spaces under the floors or roof. (See Figure 2-7)

The remaining three categories (4, 5, and 6) each have two sub-categories. In one, all members have a minimum of one-hour fire-protection, a requirement not mandated for the other subcategory.

Type 4 has non-combustible materials used in all major interior structural elements. (Figure 2-8) The use of non-combustible materials in the structure and enclosing surfaces obviously reduces the amount of fuel available in the event of fire and therefore reduces the potential fire hazard. Unprotected non-combustible members, while retaining much of their strength, may be so deformed in the event of fire to become hazardous more rapidly. Even though Type 3 has combustible materials for structural elements, their dimensions are such that the fire-hazard may be lower, due to the length of time required for fire to reduce the strength of the structure to a dangerous level.

Type 5 has interior structural elements of combustible materials, either protected or non-protected. Because of the instrinsicly greater fire hazard, the provisions for fire-stopping all concealed spaces to reduce the spread of fire became more critical.

Type 6 construction, conventional wood frame, provides the least fire-safety of all types, whether the exterior walls are wood siding, brick veneer, or stucco, and whether the structural elements are protected or unprotected, since the structural elements are combustible materials in small dimensions.

Balloon framing (Figure 2-9), developed in the nineteenth-century and permitted the rapid growth of the West, has largely been superceded by platform framing (Figure 2-10). Balloon framing has also permitted more rapid development of a fire since the two-story spaces between the studs served as excellent multiple chimneys (until fire-stops were required by the codes). Where fire-districts have been established by a community, Type 6 construction is not permitted because of its risk of combustion.

Table 2-2 indicates the fire-resistance rating required for the various components of the structural system to comply with the specific type-designation.

Separation between buildings has an influence in code enforcement toward reducing fire hazard. If the wall of a building is within 3 feet of the property line between it and an adjacent property, the wall must be built with the maximum fire-rating for that type of construction. As the distance to the property line increases, the codes provide a reduction in fire-resistance rating, up to 30 feet. The closer the wall of a building is to an adjoining building, the greater is the hazard of fire in one building causing damage to the other or of the fire spreading. Similarly, the amount of openings (windows or doors) permitted in the wall increases as the separation increases.

ALLOWABLE LIMITS

Occupancy-Type

The relationship between the increasing potential fire-hazard from Type 1 to Type 6 and the acceptability of a construction type for a specific building depends on characteristics of the use of a building, of its size, and of its location on the property.

The codes have classified the various uses to which buildings or portions may be put into categories based on similarities of the nature of the occupants and of the contents, as shown in Table 2-3.

The characteristics of the occupants, including age, probable familiarity with a building, general mobility, alertness, and number of occupants, help establish one dimension of the hazard of an occupancy-category. A second dimension is established by the quantity and the type of the contents (furniture and other furnishings, equipment, and goods) normally found at any time in each category, as well as, in some cases, their probable arrangement. In many occupancies, the contents provide a larger amount of fuel to a fire than the structure; while a code enforcement official may have control over the combustibility of the structure, he rarely has any authority over the contents (except for hazardous materials; and decorations in some categories). While it is likely that in a specific instance a lower content-hazard might be demonstrated, it is also likely that over a period of time, this level of content-hazard would be exceeded.

Basic Allowable Area

For each of the occupancy-categories, the model codes determine a maximum area for a one-story building of each construction type, the ratio to that area of the area of each additional story, and the maximum height in feet permitted. However, the codes also provide that a fire-wall establishes a boundary between one building and another; thus, what the owner or tax-assessor may see as one building, may be seen as three 'buildings' to the code enforcement official, each building having the allowable occupancy area.

This allowable area/floor in the model codes may be doubled in multi-story buildings with an increase in allowable height and stories (or tripled for a one-story building) if the building has an automatic sprinkler system, as shown in Table 2-4, which also indicates the increases allowable for one-hour protection. The effect of these modifications for all occupancy-types can be found in the building code book.

In many cases, the allowable area may also be increased significantly if adequate open space, which will always be accessible to the fire department, is provided on more than one side. "Adequate" may be defined as being 30 feet.

Table 2-5 illustrates the increase in allowable unsprinklered area/floor as a greater percentage of the perimeter of a building is adjacent to permanent open space, such as a street, or open area on the property. For example, if a square building in the center of a block is built to the property lines on either side but opens to the street on front and to a 70 foot yard to the rear, 50% of the perimeter faces open space and the allowable area/floor could be increased by 33 1/3 of the allowable unsprinklered area. Thus, if this building were of Type 4 construction unprotected but sprinklered throughout, and had 38,000 square feet per floor, it would comply with the code, since 38,000 is less than 39,667 (34,000 plus 17,000/3) for business occupancy.

Change in Use

If the use of a building is proposed to be changed from one occupancy-group to another, current code provisions require that the building must comply with all current code provisions for the proposed use. For example, if the building just discussed were to be changed from Business to Education, the allowable area/floor would decrease.

However, the building would no longer comply with the code, since unprotected Type 4 construction is permitted only for one-story Education buildings. If the construction would qualify as 1-hour protected Type 4, it would be acceptable, since 36,000 sq. ft. (allowable area/floor for multi-story protected-and-sprinklered Type 4 buildings of Education occupancy) plus 1/3 of 18,000 sq. ft. (allowable unsprinklered area) is 42,000 sq. ft. for the building with 50% adjacency to open space.

Additions

Since any proposed addition to an existing building would involve new construction, the addition must obviously comply with current code provisions. However, the nature of the connection of the addition to the existing building must be determined partially by consideration of the allowable area/floor. If the total area/floor of the building plus the addition does not exceed the allowable area/floor for the proposed occupancy-group and the building and addition are one of the lower of the types of construction, there is no problem.

If however, the area/floor of the addition would cause the total area/floor to exceed the allowable area/floor, or if the existing building already is in excess of the allowable area (which might be the case if the building has been built under an earlier code or for a different occupancy), the addition must be separated from the existing building by a fire wall; in effect, the addition must be built as a separate building.

If the addition increases the height of the building, either in feet or number of stories, the entire building must comply with current code provisions.

MINIMUM REQUIRED AREAS

Codes provide require minimum areas for rooms.

The Housing Code provides that no more than two families may occupy a dwelling, that a building occupied by more than two families must either be a multiple dwelling (with provisions for independent living and cooking in each dwelling unit) or a rooming house (a dwelling with one or more rooming units not for cooking or eating and let to persons unrelated to the family).

Each dwelling unit must have at least 150 square feet for its first occupant and 100 square feet of floor area for each additional occupant, in the total of all habitable rooms (rooms used for living, sleeping, eating, or cooking). A family of six thus would need a minimum of 650 square feet, plus bathrooms and storage areas.

Each sleeping room must have 70 square feet for one occupant, or 50 square feet for each occupant, or a minimum of 100 square feet for a 2 person bedroom. Habitable rooms must have a ceiling height of at least 7 feet over 50% of the room, and in the case of sloping ceilings, only that area with a five foot ceiling or more can be included toward the required area (Figure 2-11).

The Building Code requires 7'6" ceiling over 50% of a room. All rooms in a dwelling unit must be at least 70 square feet, except that one must be at least 150 square feet, and a kitchen need only have 50. Sleeping rooms must have 70 square feet for the first occupant, and 50 for each additional occupant, or a minimum of 120 sq. ft. for two. Total area per dwelling unit is the same as in the Housing Code. For the family of six with three bedrooms, of the 650 square foot minimum, 360 square feet would be needed for the bedrooms, and 290 square feet for living, eating and cooking.

SITE

General

In addition to its location on the property, in terms of separation from adjacent properties and provision of open space, other characteristics of the site of a building should be observed. The nature of the soil, the nature of the form of the surface on which it is built (its topography), the climate to which a building is exposed, and the nature of the materials on the earth surfaces around a building should be observed closely to provide an indication of problems to be checked.

In property maintenance inspection the Housing Code provides that abandoned items (such as motor vehicles, appliances, building materials and rubbish), weeds; dead trees, trash and garbage must be removed from the property.

Soil

A building rests on the earth, and all loads ultimately must be transferred to the soil on which the building is supported. The nature of the soil, and of the way in which the elements of the building relate to the soil, may cause problems in the condition of the building. The subsurface material and its structure, and the presence of water, are key data in analyzing foundations.

Soils can be classified (Table 2-6) very simply on the basis of grain size and whether they are organic or inorganic. The firmest support, obviously, would be directly on rock. Gravel, and clean sand provide a relatively good base, because of stability and drainage. If they are loose, there will be initial settlement as loads are applied to them, but firmness is rapidly developed. However, the fine sands and sand-silt mixture have greater tendency to 'flow' and uneven settlement may have occurred, causing cracks in the foundations and possibly in the superstructure.

The clays vary widely in structural characteristics. The soft clays compress under load, causing settlement, and if they are silty may flow. Organic and certain other clays vary in their water content, and swell when wet or subjected to frost, causing heaving. Sands or clays containing silt frequently have poor internal drainage, and water pressure may have built up against foundation walls, causing bulging or buckling.

Table 2-6 also shows the average allowable bearing capacity of each soil type. The actual bearing capacity of the particular soil at a specific site can be determined by test. The foundations for a building must have been built so as to adequately transfer the loads from a building to the soil on which the foundations rest.

A second factor is subsurface water: the moisture content of the soil, internal and surface drainage, and the location of the water table. The water table is the underground surface below which all spaces between soil grains are filled with water. Normally this is a sloping, flowing surface, which roughly follows the ground levels above, and slopes down to ponds, lakes, streams, seeps, or springs, where it intersects the ground surface. Its depth below ground can vary markedly, however, and can fluctuate seasonally or over longer periods. Impervious subsurface rock or soil layers can also modify the water table, trapping water above or below themselves, or guiding it through seams.

A high water table may cause problems with flooded basements and unstable foundations. Excessive surface drainage, if improperly graded, may have washed out soil under foundations, or caused dry rot in wood. The nature of surface planting or other vegetation can also aid or abet this condition.

Topography

The nature of the surfaces surrounding the building should be examined, not only on its own property but also on adjacent properties. Most simply, the site of a building can be categorized as being flat; sloping towards the building; or sloping from the building (Figure 2-12).

If the property is essentially flat, with a slight grade (about two percent) down from the building, access is simply achieved and drainage is readily handled.

If the land slopes more steeply from the building, access may be more awkward, but drainage problems can be minimized. However, if the land slopes away in all directions (a building on a knoll), the effects of wind may have been increased, by 20%, over flat land.

If the land slopes down toward the buiding, drainage can be an extremely important factor. The water table depth, combined with the effects of surface vegetation, the nature of the soil, wind, and orientation, may have seriously damaged the building materials (especially wood).

It is important not only to consider the nature of the existing slopes but also, by observation of adjacent property, to determine whether the site has been modified by excavation or fill. Even though the surface has been changed, the nature of the subsurface may not have been altered.

Climate

The five major elements of climate are temperature, humidity, precipitation, air movement, and solar radiation. In addition. three other elements of climate which also shape and define local climate are sky condition, vegetation, and special meteorological events. These elements of climate which affect human comfort also frequently influenced the design, construction, and durability of buildings, until technology provided the means to avoid local climatic determinants. In terms of defining broad categories of climate-characteristics, each of four regions of the United States (see Figure 2-13) has an inherent character of weather patterns which distinguish it from the others, even though at one time or another each also displays characteristics of another.

COOL REGIONS OF THE UNITED STATES

A wide range of temperatures is characteristic of cool regions. Temperatures of minus 30° F (-34.4° C) to plus 100° F (37.8° C) have been recorded. Hot summers and cold winters, with persistent winds year round, generally out of the NW and SE, are the primary identifiable traits of cool regions. Also, the northern location most often associated with cool climates receives less solar radiation than southern locations.

The Cape Cod housing style was developed in response to the harsh climatic conditions of the New England and Atlantic seaboard area. Its compact floor plan, small exterior wall and roof area, and small windows and low ceilings made the house easily heated by the centrally located fireplace. Later, south-facing dormers allowed for ventilation, lighting, and views at the second level of the two-story house. It could be rapidly and easily constructed on a variety of sites, and was relatively inexpensive.

The early housing styles of middle America were uniquely adapted to the cold and windy conditions of the Midwest and Great Plains. Originally consisting of one room log cabins or sod huts, the housing styles gradually changed as the population grew and larger settlements developed. Although borrowing numerous design and construction techniques from the East, Midwest housing styles evolved into unique designs suitable to the new climatic and geographic conditions. The houses were easily heated, resistant to strong winds, and adaptable to variations in orientation and topography.

A case in point is the traditional Farm House. The house design consisted of several buildings, sometimes connected, organized around a central yard. The buildings were usually one story in height, with a sleeping loft. They were sited not only to block cold winter winds but also to capture the cooling summer breezes.

TEMPERATE REGIONS

An equal distribution of overheated and underheated periods is characteristic of temperate regions. Seasonal winds from the NW and S along with periods of high humidity and large amounts of precipitation are common traits of temperate regions. Intermittant periods of clear sunny days are followed by extended periods of cloudy overcast days.

Typical of the house styles of the Atlantic seaboard and Tidewater Virginia are the decorative center entrance, spacious central hallway, flanking chimneys at each end, brick exterior walls and frequently symmetrical wings and generous porch areas to capture east, south, and westerly breezes. Higher ceilings and long windows also were frequently used to ameliorate the climate.

HOT-HUMID REGIONS

High temperature and consistent vapor pressures are characteristic of hot-humid regions. Wind velocities and direction vary throughout the year and throughout the day. Wind velocities of up to 120 mph may accompany hurricanes which can be expected from S-SE directions.

The hot-humid climate of the South Atlantic Seaboard and Gulf coast is suited to housing styles which allow maximum heat loss and minimum heat gain during the summer months. A housing style was developed which was responsive to both of these concerns and which incorporates large window and louver areas for natural ventilation, and extended roof overhangs for protection from direct solar heat gain. The floor plan arrangement is open and spread out to capture and channel air movement through the house.

HOT-ARID REGIONS

Hot-arid regions are characterized by clear sky, dry atmosphere, extended periods of overheating, and a large daily temperature range. Wind direction is generally along an E-W axis with variations between day and evening.

The architectural styles of the Southwest evolved from a combination of climatic and cultural influences. Adobe construction, characteristic of this region, is well-suited to the wide fluctuation in temperature experienced between day and night. The adobe walls act as a heat sink, absorbing the heat during the day and radiating it to the interior at night. The various Indian communities of the region developed this unique construction technique to a fine art prior to the arrival of the Spaniards who called the native inhabitants Pueblo Indians because of the communal environment in which they lived. The Spaniards adopted the same materials of adobe and native rock for their construction.

Climatic Factors

While climate depends on all five factors (temperature, humidity, precipitation, wind, and radiation), each of the elements of climate is of importance individually as each affects a particular building. There frequently is a distinct difference between the macroclimate (the climate of the overall community or area) and the microclimate (the climate of a specific building site), a difference equivalent in many locations to a 300-400 mile variation.

Temperature is primarily related to incoming solar radiation, which in the macroclimate varies with the latitude. One effect of temperature is that of frost penetration into the earth, shown in Figure 2-14, which determines the depth of foundations to obtain stability, and the depth of underground piping. However, depth of freezing of the ground under the foundation of a specific building may vary from that of the community, depending on the orientation of that wall of the building to the sun and the presence of ground water, and the presence on sloping sites of a barrier to the flow of cold down the slope, creating a frost-hollow.

Also of concern to the inspector is the wear-and tear of the materials in a building as a result of alternative freezing and thawing, wetting and drying. These conditions are the result of thermal variations daily and seasonally in the climate, but also the result of orientation of different portions of the building; the south side of a building may receive 100 times as much solar radiation (and therefore, heat) as the north side.

One effect of wind is in assisting the penetration of water into the surfaces of the building. Although the code provides data as to the velocity of winds to be used in the structural design of buildings (Figure 2-15), this information is based on 30 feet or greater height. At 5 feet above the ground, wind velocity may only be ¾ of the 30-foot velocity, unless modified by the presence of buildings or other surfaces, which can make a significant difference.

The effects of precipitation (Figure 2-16), in the forms of snow, rain, hail, sleet or fog will be of concern to the inspector in terms of their impact on the durability of the materials and construction of a building. The combined effect of wind and ground slope modify the basic wetting patterns, and the ability of the surfaces surrounding the building to cope with sudden deluges of water can cause erosion of the earth. Similarly, the combined effect of orientation of a roof and the presence of insulation in the roof/ceiling construction can affect the durability of roofing materials.

Planting and Surface Materials

The nature of the materials used on the land surrounding a building are of two types: the natural and growing materials such as lawns, shrubs, and trees; and hard materials, such as brick, stone, asphalt, or concrete paving. With reference to the slope and type of soil, these materials may either reduce or aggravate moisture and drainage problems. They may also serve to reduce or worsen the impact of the climatic factors of temperature, solar radiation, and wind; and may have either a beneficial or deleterious effect on the durability of the building materials or construction, especially, for example, materials such as ivy growing on masonry walls. Other than the Housing Code provisions related to care of the premeses, safety, and sanitary conditions, no code concerns are involved.

In all of the site factors described, the concern of the inspector is to observe conditions which may have caused problems in the building and, in the event that a potential problem may have been created, to look more carefully at the parts of the building which may have been effected.

MINIMUM UNIFORMLY DISTRIBUTED LIVE LOADS

Occupancy or Use	Live Load (Psf)
Assembly halls and other places of assembly:	
Fixed seats	50
Movable seats	100
Platforms (assembly)	100
Balcony (exterior)	60
On one and two family residences	40
Bowling alleys, poolrooms and similar recreation areas	75
Corridors:	
First Floor	100
Other floors, same as occupancy served except as indicated	100
Dance halls and ballrooms	100
Dining rooms and restaurants	100
Garages (passenger cars only)	50
Gymnasiums, main floors and balconies	100
Hospitals:	
Operating rooms, laboratories	60
Private rooms	40
Wards	40
Corridors, above first floor	80
Libraries:	
Reading rooms	60
Stack rooms (books and shelving at 65 pcf)	125
Corridors, above first floor	80
Manufacturing:	
Light	100
Heavy	150
Marquees	75
Office Buildings:	
Offices	50
Lobbies	100
Corridors, above first floor	80
File and computer rooms require heavier loads based upon anticipated occupancy	
Penal institutions:	
Cell blocks	40
Corridors	100
Residential:	
Multifamily houses:	
Private apartments	40
Public rooms	100
Corridors	80
Dwellings:	
Sleeping rooms	30
Attic with storage	30
Attics without storage	10
All other rooms	40
Hotels:	
Guest rooms	40
Public rooms	100
Corridors serving public rooms	100
Corridors	80
Schools:	
Classrooms	40
Corridors	80
Sidewalks, vehicular driveways and yards, subject to trucking	200
Stairs and exitways	100
Storage warehouse:	
Light	125
Heavy	250
Stores:	
Retail:	
First floor, rooms	75
Upper floors	75
Wholesale	100
Theaters:	
Aisles, corridors and lobbies	100
Orchestra floors	50
Balconies	50
Stage floors	150

TABLE 2-1

FIRE PROTECTIVE REQUIREMENTS IN HOURS

COMPONENT	CONSTRUCTION TYPE 1	2	3	4	5	6
WALLS						
Fire	4	4	4	4	4	4
Exterior:						
Bearing	4	3	3	2	3	1
Non-Bearing	3	3	3	2	3	0
Interior:						
Bearing	4	3	2	1	1	0
Non-Bearing	varies by occupancy					
FRAMING						
Columns:						
One story	3	2	1	1	1	0
More than One	4	3	1	1	1	0
Beams, Girders:						
One story	3	2	1	1	1	0
More than One	4	3	1	1	1	0
FLOORS	3	2	1	1	1	0
ROOF	1½	1	1	1	1	0

TABLE 2-2

OCCUPANCY GROUPS

Occupancy		Description	
A		ASSEMBLY-	
	1a		Large-Working Stage
	1b		Non-working Stage
	2a		Small-Working Stage
	2b		Non-Working Stage
B		BUSINESS	
E		EDUCATIONAL	
F		FACTORY-INDUSTRIAL	
H		HAZARDOUS	
I		INSTITUTIONAL-	
	Ir		Restrained
	Ir		Unrestrained
M		MERCANTILE	
R		RESIDENTIAL	
S		STORAGE	

TABLE 2-3

	TYPE OF CONSTRUCTION					
	TYPE 1, 2,3		TYPE 4,5,6			
			1-Hour		Unprot.	
Maximum Height	65′		65′		55′	
	uns	spr	uns	spr	uns	upr
Max. No. of Stories						
Area: Multi-story	1.0	2.0	1.5	3.0	1.0	2.0
One Story	1.0	3.0	1.5	4.5	1.0	3.0

TABLE 2-4

Increase based on F/P%

F/P%	I%	F/P%	I%	F/P%	I%
26	1.33	51	34.67	76	68.00
27	2.67	52	36.00	77	69.33
28	4.00	53	37.33	78	70.67
29	5.33	54	38.67	79	72.00
30	6.67	55	40.00	80	73.33
31	8.00	56	41.33	81	74.67
32	9.33	57	42.67	82	76.00
33	10.67	58	44.00	83	77.33
34	12.00	59	45.33	84	78.67
35	13.33	60	46.67	85	80.00
36	14.67	61	48.00	86	81.33
37	16.00	62	49.33	87	82.67
38	17.33	63	50.67	88	84.00
39	18.67	64	52.00	89	85.33
40	20.00	65	53.33	90	86.67
41	21.33	66	54.67	91	88.00
42	22.67	67	56.00	92	89.33
43	24.00	68	57.33	93	90.67
44	25.33	69	58.67	94	92.00
45	26.67	70	60.00	95	93.33
46	28.00	71	61.33	96	94.67
47	29.33	72	62.67	97	96.00
48	30.67	73	64.00	98	97.33
49	32.00	74	65.33	99	98.67
50	33.33	75	66.67	100	100.00

TABLE 2-5

TYPES OF SOILS AND THEIR DESIGN PROPERTIES

Soil group	Soil description	Allowable bearing in pounds per square foot with medium compaction or stiffness[3]	Drainage characteristics[2]	Frost heave potential	Volume change potential expansion
Group I Excellent	Well-graded gravels, gravel sand mixtures, little or no fines.	8000	Good	Low	Low
	Poorly graded gravels or gravel sand mixtures little or no fines.	8000	Good	Low	Low
	Well-graded sands, gravelly sands, little or no fines.	6000	Good	Low	Low
	Poorly graded sands or gravelly sands, little or no fines.	5000	Good	Low	Low
	Silty gravels, gravel-sand-silt mixtures.	4000	Good	Medium	Low
	Silty sand, sand-silt mixtures.	4000	Good	Medium	Low
Group II Fair to Good	Clayey gravels, gravel-sand-clay mixtures.	4000	Medium	Medium	Low
	Clayey sands, sand-clay mixture	4000	Medium	Medium	Low
	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	2000	Medium	High	Low
	Inorganic clays of low to medium plasticity, gravelly clays, sands clays, silty clays, lean clays.	2000	Medium	Medium	Medium[1]
Group III Poor	Inorganic clays of high plasticity, fat clays	2000	Poor	Medium	High[1]
	Inorganic silts, micaceous or distomaceous fine sandy or silty soils, elastic silts	2000	Poor	High	High
Group IV Unsatisfactory	Organic silts and organic silty clays of low plasticity	400	Poor	Medium	Medium
	Organic clays of medium to high plasticity, organic silts	-0-	Unsatisfactory	Medium	High
	Peet and other highly organic soils	-0-	Unsatisfactory	Medium	High

[1] Dangerous expansion might occur if these two soil types are dry but subject to future wetting.

[2] The percolation rate for good drainage is over 4 inches per hour, medium drainage is 2 to 4 inches per hour, and poor is less than 2 inches per hour.

[3] Allowable bearing value may be increased 25 percent for very compact, coarse grained gravelly or sandy soils or very stiff fine-grained clayey or silty soils. Allowable bearing value shall be decreased 25 percent for loose, coarse-grained gravelly or sandy soils, or soft, fine-grained clayer or silty soils.

TABLE 2-6

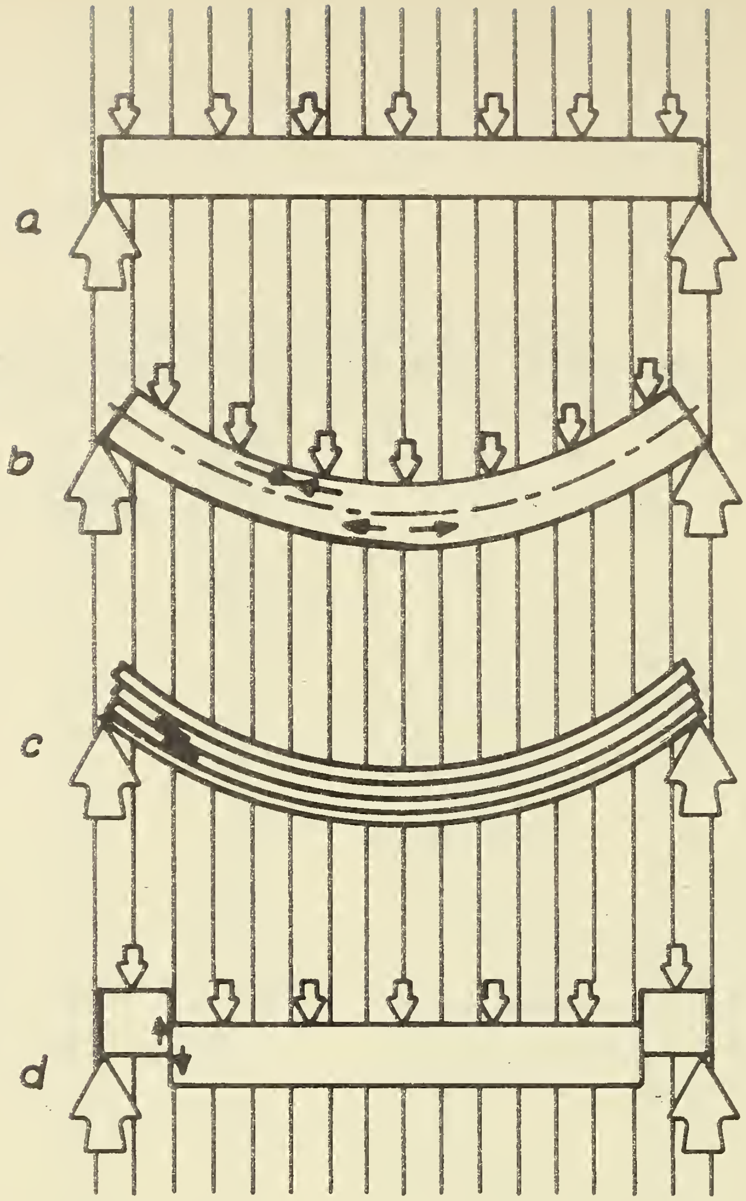


Figure 2-1

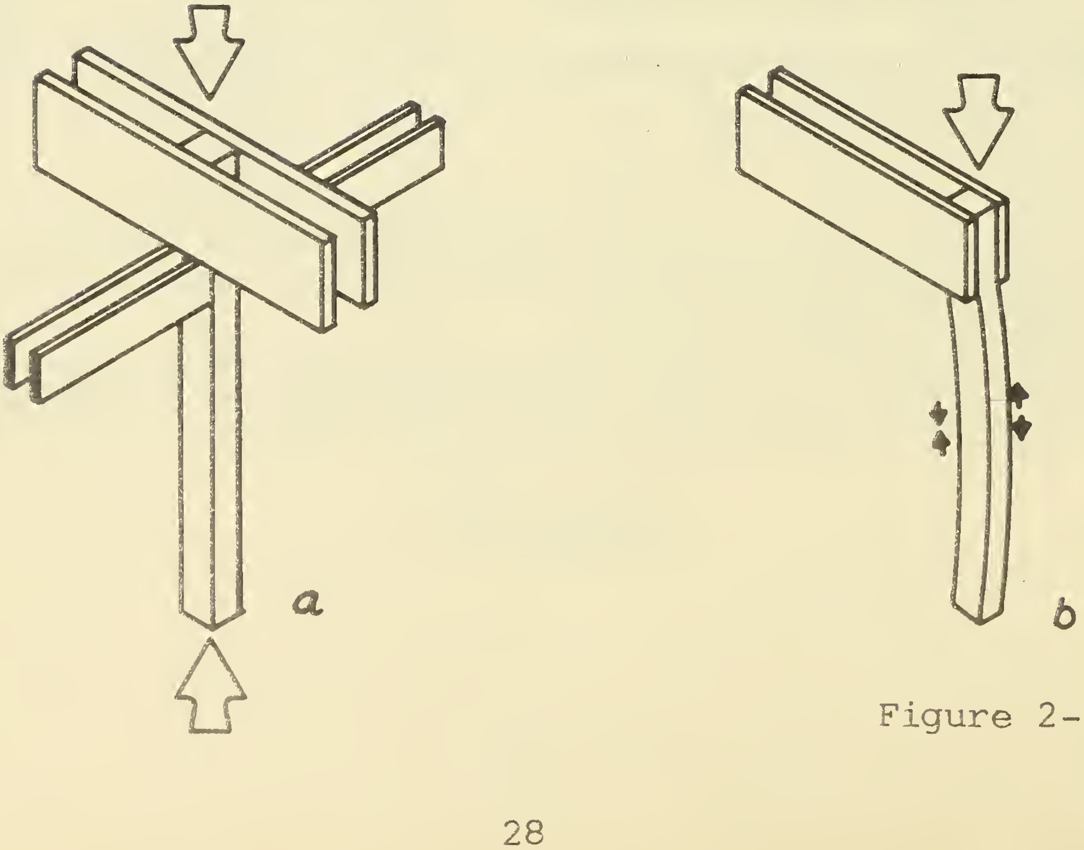


Figure 2-2

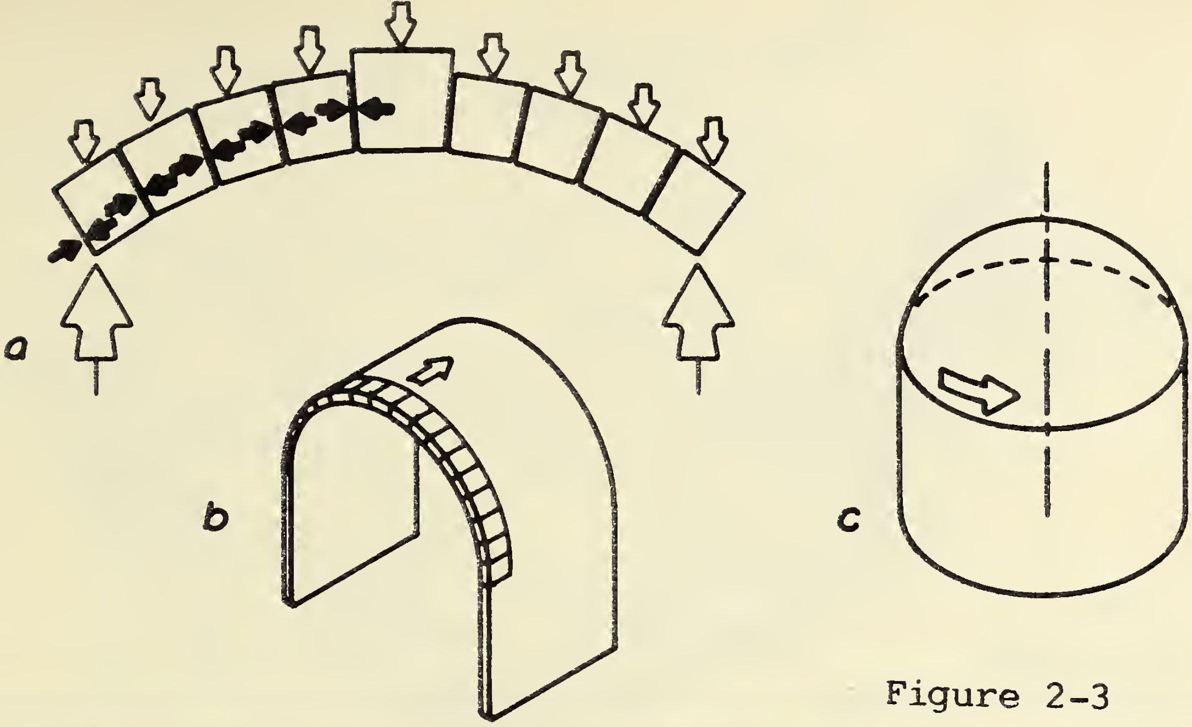


Figure 2-3

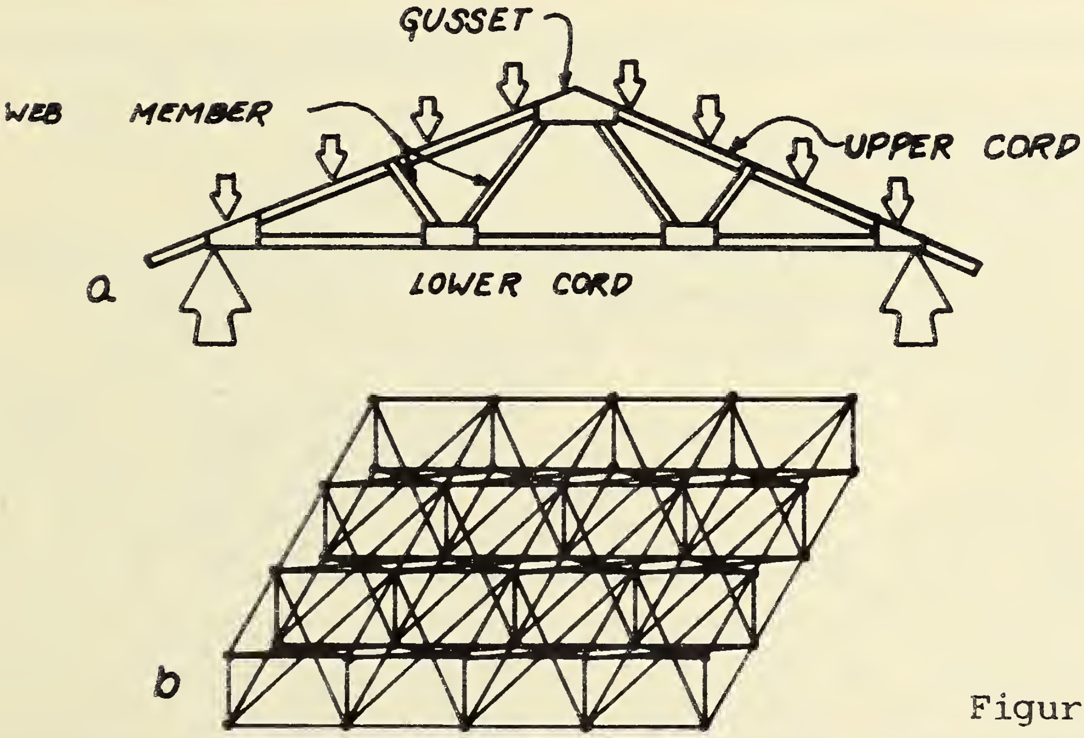
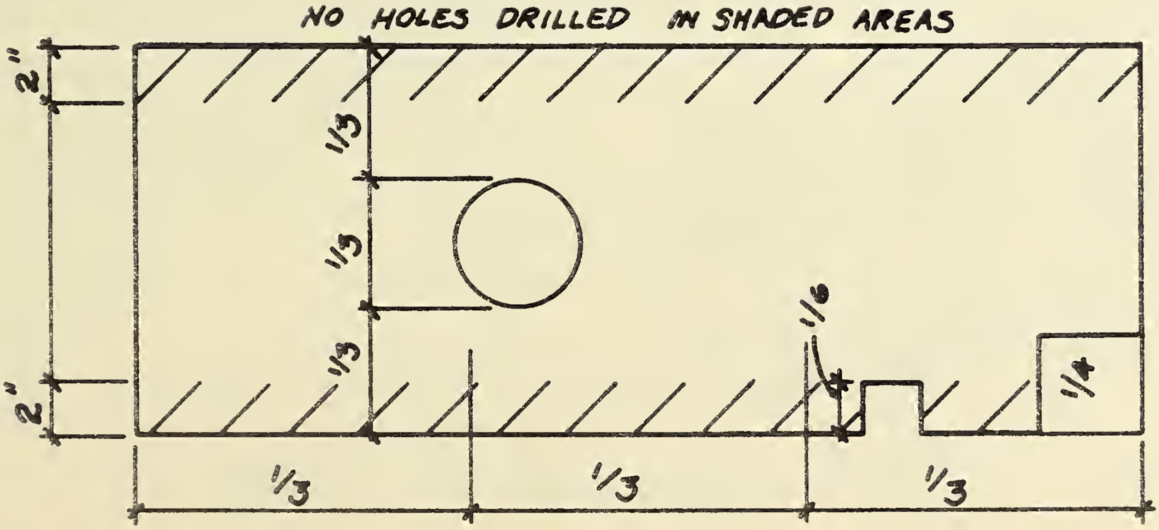
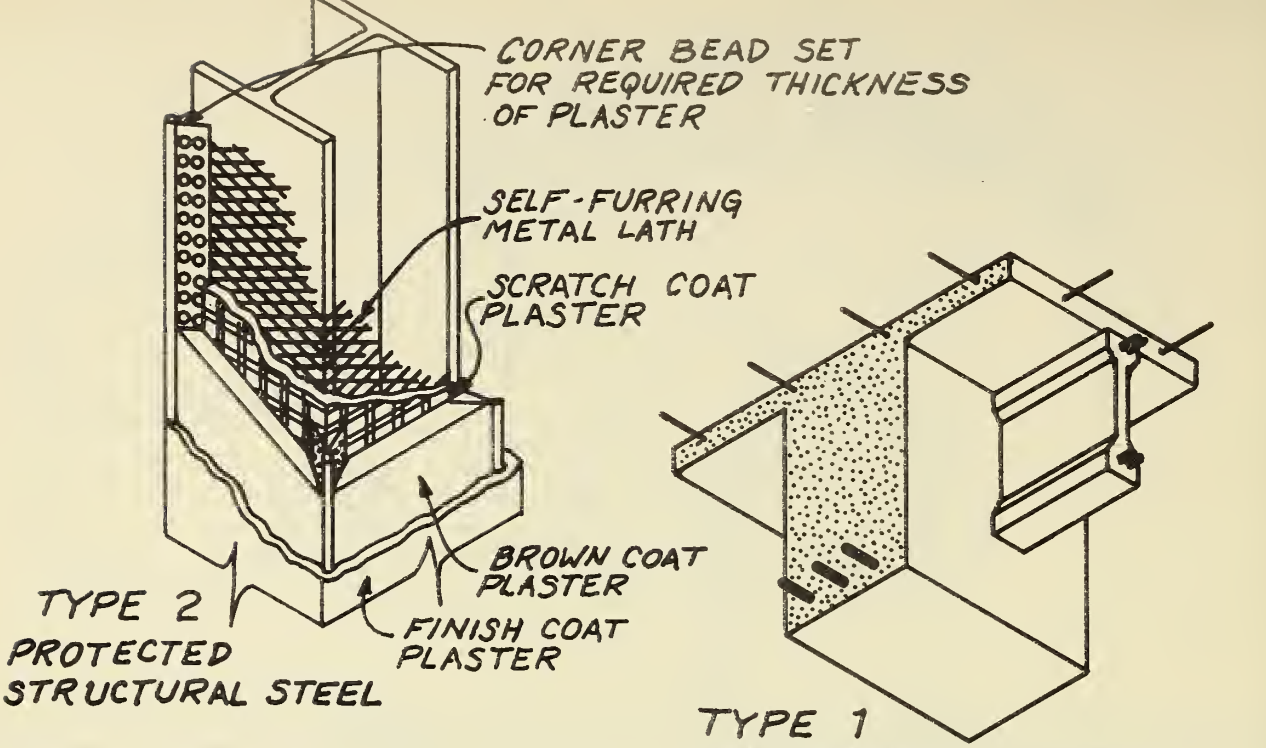


Figure 2-4

Figure 2-5





TYPE 2
PROTECTED
STRUCTURAL STEEL

TYPE 1
REINFORCED CONCRETE

Figure 2-6

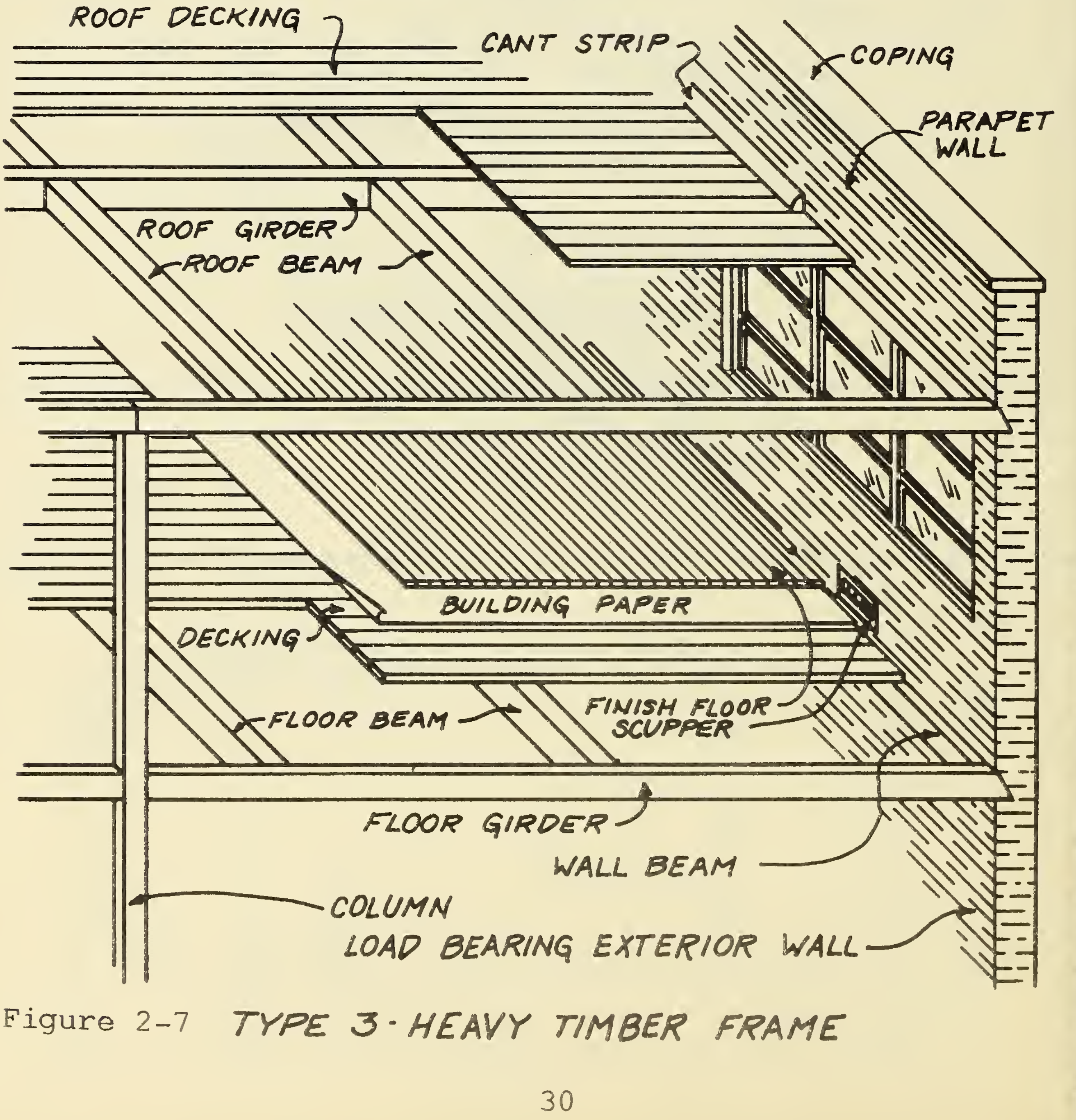
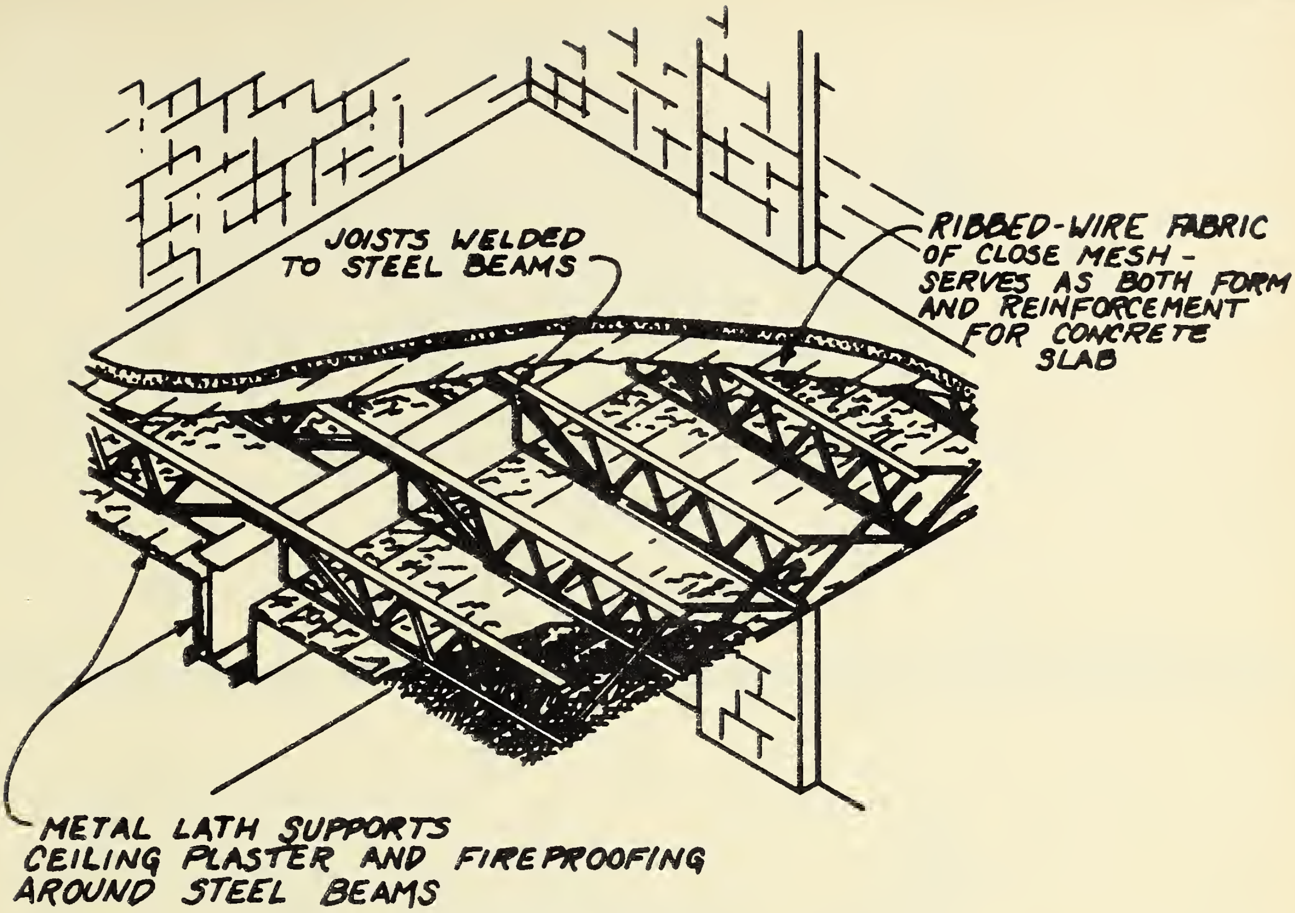


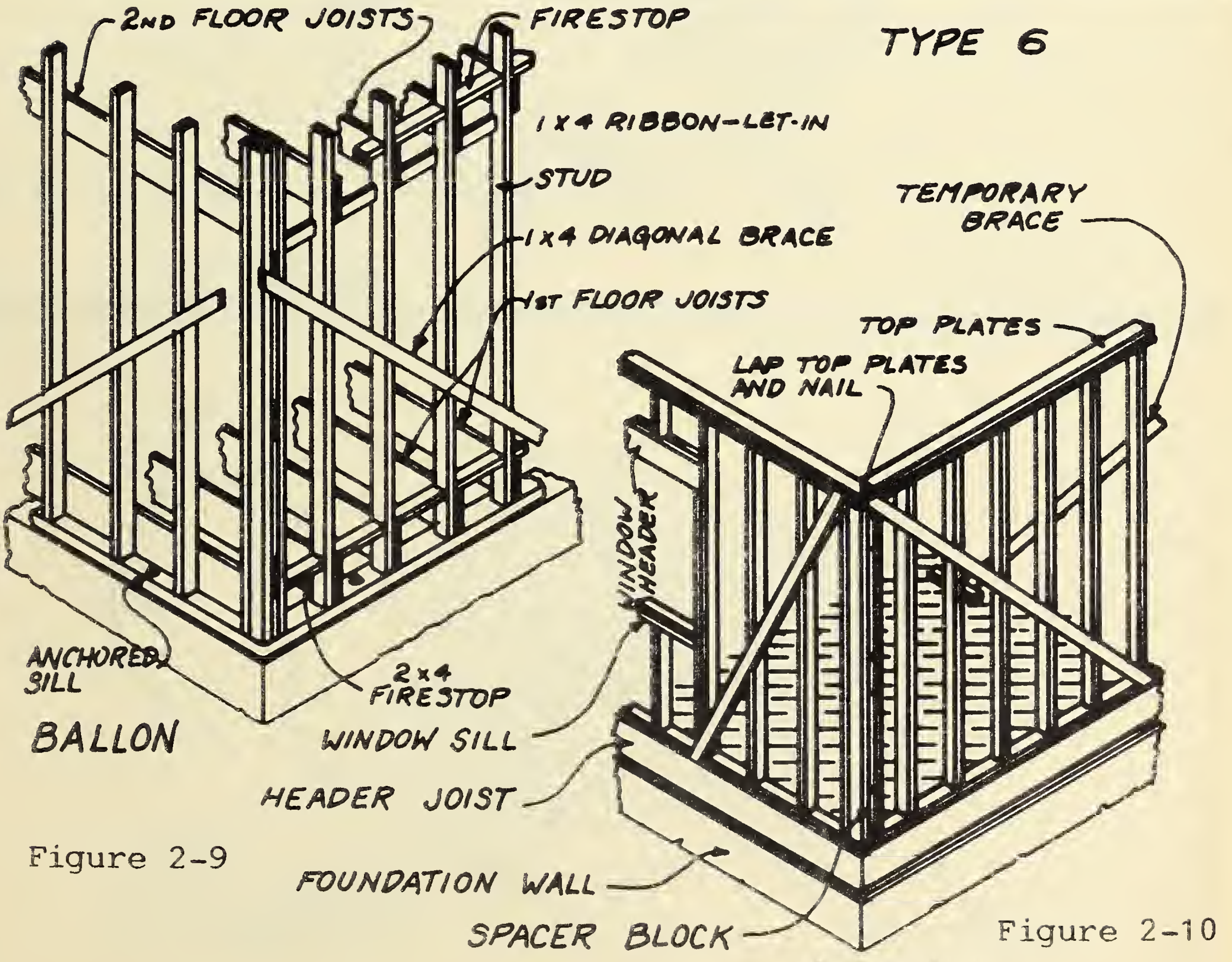
Figure 2-7 TYPE 3 - HEAVY TIMBER FRAME


JOISTS WELDED TO STEEL BEAMS
RIBBED-WIRE FABRIC OF CLOSE MESH - SERVES AS BOTH FORM AND REINFORCEMENT FOR CONCRETE SLAB
METAL LATH SUPPORTS CEILING PLASTER AND FIREPROOFING AROUND STEEL BEAMS

TYPE 4

Figure 2-8

TYPE 6



BALLON

Figure 2-9

Figure 2-10

PLATFORM

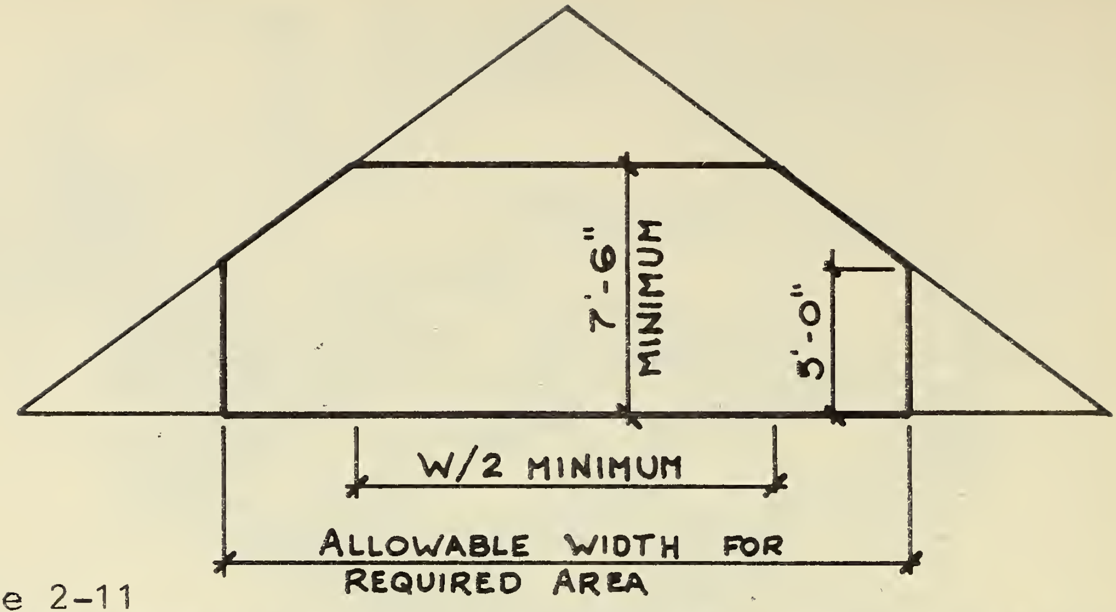


Figure 2-11

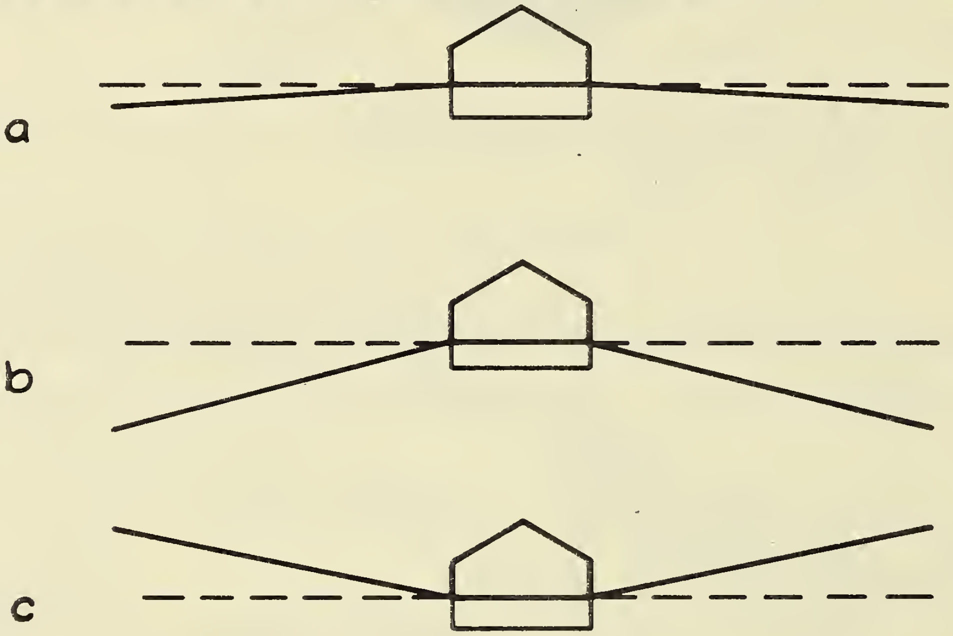


Figure 2-12

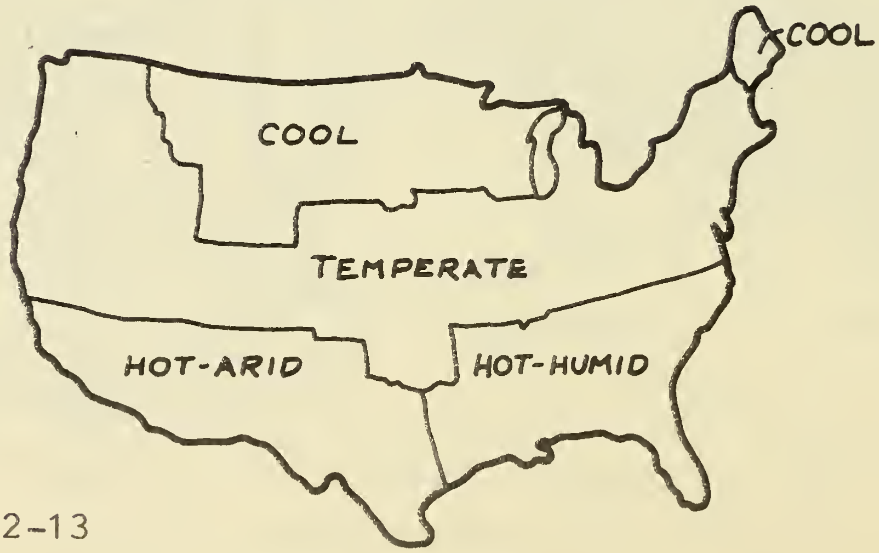


Figure 2-13

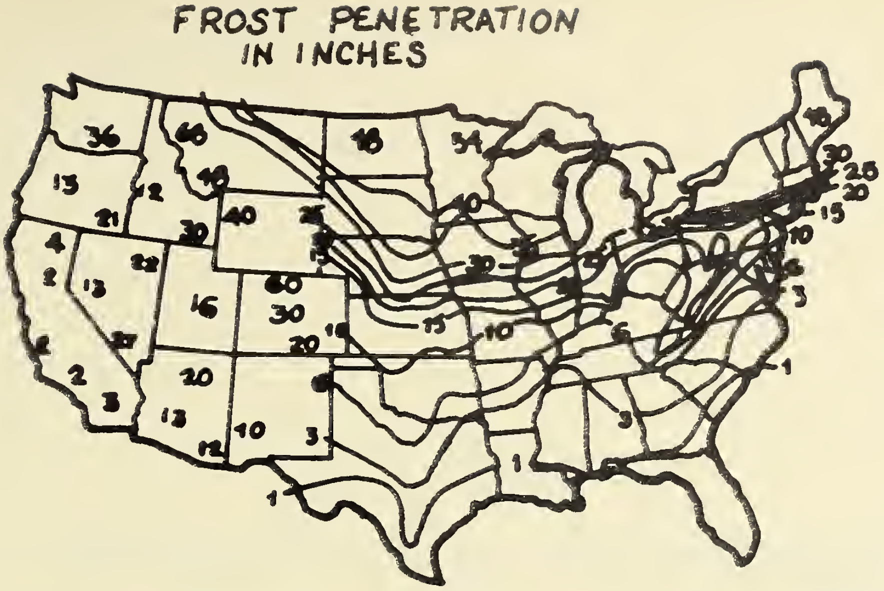


Figure 2-14

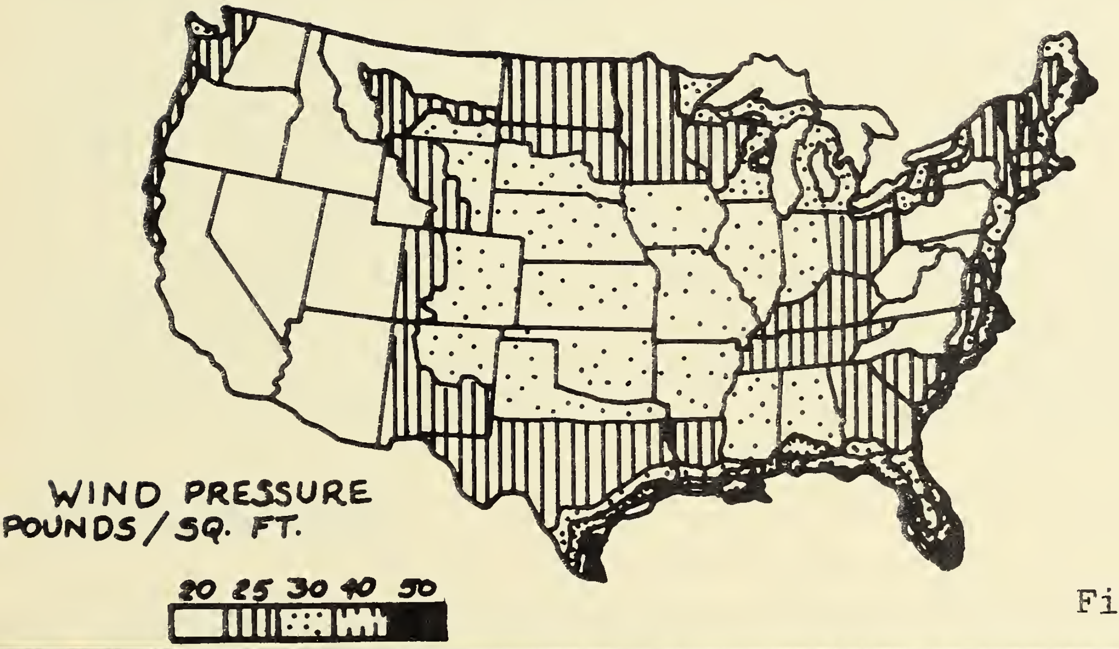


Figure 2-15

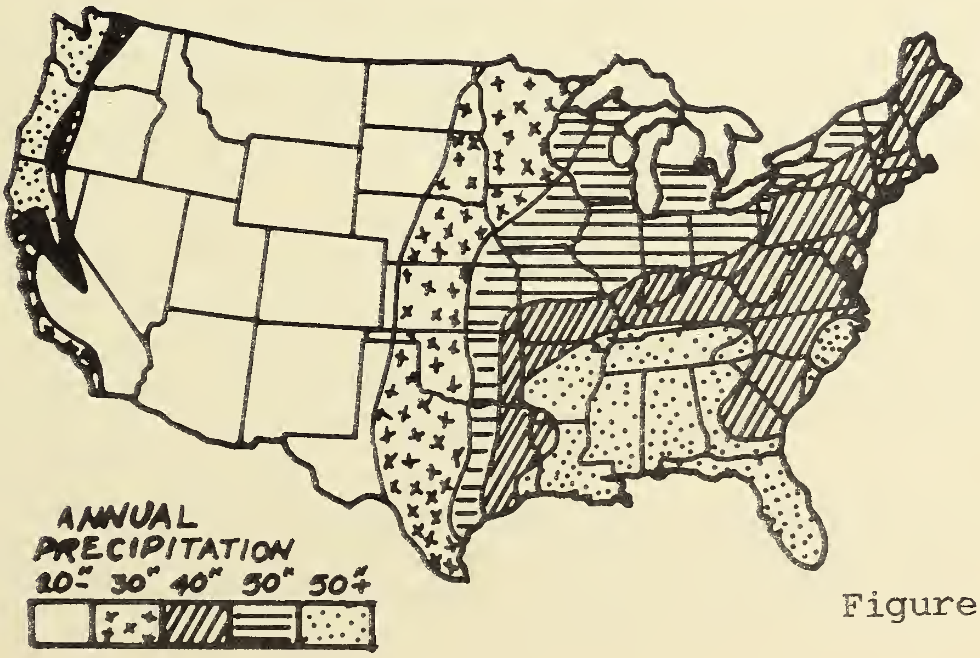


Figure 2-16

CHAPTER III
STRUCTURAL SYSTEMS

The structural elements of a building—the foundation, floors, walls, and roof—(Figure 3-1) must be so maintained as to be structurally sound, showing no evidence of deterioration which would render them incapable of carrying normal loads. The floors, walls, and ceiling must be substantially rodent proof and safe to use. Certain structural items should be recognized as unsafe by the inspector. For example, a beam that has sagged or slanted may cause a portion of or an entire floor to sag or slope. Where a sagging or sloping floor is found, examine the ceiling of the room below or the basement for a broken or dropped girder or joist.

Doors and windows that are not level will not close completely. It may be possible to see outside light through openings around window rails and door jambs. If an inspector detects such a situation, the condition of the supporting girders, girts, posts, and studs should be questioned, since this condition is evidence that some of these members may be termite-infested, rotted, etc., and may be causing the outside wall to sag.

FOUNDATIONS

The foundation is a critical part of most buildings, representing an appreciable portion of the cost, and if improperly designed or constructed, causes problems expensive to repair. Many of the problems associated with the foundation are the result of an inadequate or incorrect evaluation of subsurface conditions. For other portions of the structural system, fairly positive and valid data are available and the design can be more accurate. Although subsurface conditions can be determined with far greater accuracy today, in the past knowledge of the bearing capacity and stress distribution of the soils was limited.

The basic function of the foundation is to transfer the total load of the building into the ground. Although the major portion of this load is vertical, foundations may also have to resist lateral pressue from the earth due to the weight of the soil or surface loads (i.e. trucks) or pressure of ground water or seismic forces. The nature of the foundation chosen will depend on the nature of the building superstructure above it, on the nature of the soil, and on the location; types used can be classified as point, linear, or planar (See Figure 3-2).

Materials used for footings generally will be of concrete, either plain or reinforced, although in a few older buildings, large flat stones may have been used. The foundation above the footing may be of concrete, either plain or reinforced, or of masonry, stone, brick or concrete block; and in the case of posts on individual footings, of either wood or metal.

Regardless of type, the base of footings must be below frost depth to avoid possible heaving of frozen earth. The bottom of footings should be level.

Individual footings, in effect point-type foundations, carry the load downward from a column, post, or pier (Figure 3-3).

The area of a spread footing must be sufficient to distribute the load over an area of earth so that the bearing pressure of the soil is not exceeded. For example, if a footing for a load of 18,000 pounds is supported on soil having 2,000 psf bearing capacity, the area of the footing should be 9 square feet or 3' x 3', whereas if the bearing capacity were 4,000 psf, an area of 4.50 square foot or 2'-1½' square is adequate.

While some codes, primarily for dwellings, only prescribe a thickness, the thickness should be determined as though the footing were a beam with inverted loading (Figure 3-4a). If the thickness is inadequate, the unbalanced forces of the soil pressure and the load may cause vertical shear in the footing (Figure 3-4b).

The second type of individual footing is the pile. (Figure 3-5). Unlike spread footings, pile foundations generally depend on the friction of the sides or exterior of the pile against the earth into which they have been driven. Piles may be wood, steel, or concrete. The nature of the soil is a major determinant of the friction-value.

Piles are generally used only where the soil has insufficient bearing capacity for spread footings, in locations where the structure supported must be raised above the ground surface to avoid high water or storm surges (beaches, swamps, etc.), or on steep slopes to avoid drainage problems and reduce excavation problems. Design and installation of pile foundations frequently requires competent engineering services.

Whereas individual foundations represent a point-transfer of loading, the more common linear type transfers the loads over a larger area. If the superstructure above is a bearing wall, the spread footing and foundation may be combined of individual and wall footings. The materials used are the same as for point foundations.

The bottom of a spread wall-footing must be level; (Figure 3-6a); if the foundation should be in sloping ground, the footing may be stepped (Figure 3-6b) to avoid excessive excavation. As in an individual footing, the relationship between the thickness of the footing and its width is critical. One frequent rule-of-thumb used to determine the thickness of footings is indicated in Figure 3-7. However, the width of the footing can be increased without causing shear if adequate reinforcing is placed in the footing (Figure 3-6c). Reinforcing may also be used longitudinally in a footing to provide stiffening and rigidity (Figure 3-6d).

Since the foundation wall above the footing is continuous, in addition to the vertical loads transferred from above it must also resist lateral loads from earth-pressure (see Figure 3-8), which become greater as the depth of the foundation-wall increases, from a crawl-space to a full basement. Code provisions limit the height and/or length of the foundation wall depending on the nature and the depth of the earth. The difference in levels of the earth inside and outside the foundation is known as the unbalanced fill. (Table 3-1).

In addition to providing strength, the foundation wall also serves as a barrier to the flow of water (either sub-surface or seepage from surface drainage) and, therefore usually should have damp-proofing on its exterior surface with either a membrane of water-proof material or a coating of portland cement mortar. The membrane may consist of plastic sheeting or a sandwich of standard roofing felt joined and covered with tar or asphalt. The purpose of waterproofing the foundation walls is to prevent water from penetrating the wall material and leaving the basement or cellar walls damp. A drainage system may be necessary also.

In locations where the nature of soil is inadequate to sustain spread loads, and piles cannot be used, it may be necessary to use the third type of foundation, planar (Figure 3-9). Mat foundations are used in order to utilize the entire floor area as the bearing surface, and the foundation walls and floor slab must be engineered as a unit which "floats" as a boat. Reinforced concrete is the only feasible material.

The Housing Code provides that building foundations be maintained in order that they be safe and remain capable of supporting normal loads.

Although it is usually difficult to determine the condition of footings without excavating the foundation, a footing in a state of disrepair or lack of a footing will usually be indicated either by large cracks or by settlement in the foundation walls (Figure 3-10).

Foundation wall cracks are usually diagonal, starting from the top, the bottom, or the end of the wall. Cracks that do not extend to at least one edge of the wall may not be caused by foundation problems. Such wall cracks may be due to other structural problems and should also be reported.

Holes in the foundation walls are a common finding in many old houses. These holes may be caused by missing bricks or blocks. Holes and cracks in a foundation wall are undesirable because they make a convenient entry for rodents and vermin, and also indicate the possibility of further structural deterioration. These holes should not be confused with adequately installed vents in the foundation wall that permit ventilation and prevent moisture entrapment.

A prime example of a technically complex situation that an inspector might observe is a leaning, buckling or bulging foundation or bearing wall. This problem may be the result of a number of hidden or interacting problems. For example, it may be the result of differential building settlement or failure of a structural beam or girder. It is the inspector's responsibility to note the problem.

Evidence of ineffective waterproofing or moisture proofing will be indicated by water or moisture marks on the floor and walls.

FLOORS

The floors of the building serve primarily to provide the working surface on which the activities of the building occur. Structurally they function to transfer the loads of the occupants, equipment, and stored materials to the vertical support elements, but may also serve as horizontal bracing for the walls (especially foundation walls against earth pressure and the loads of earthmoving equipment during backfill), and as horizontal shear panels for seismic loads if properly designed. In addition, the floor serves as a separation between the space above and below, and if fire-resistive construction is required, must have a fire-resistance rating.

Slabs

Slab floors are the simplest floors, serving as working surface primarily. Concrete, plain or reinforced, is the only material now used, although wood block, structural clay tile, and brick have been used earlier.

If the floor is on a slab-on-grade, (Figure 3-11a) reinforcing bars may have been used, although generally only wire-mesh is used, since the earth beneath provides structural support. If the earth under a slab has not been properly compacted after backfilling, and has subsequently subsided, or been washed away because of improper drainage, cracking may have resulted due to lack of uniform support (Figure 3-11b). This condition may be accentuated if the edges of the slab have been supported by the foundation for either the exterior walls or the internal columns (Figure 3-12). A "floating" slab avoids this problem but subsequent internal settling may cause a difference in level at door-openings, or around columns.

A moisture-barrier aids in curing the concrete, and is required by the code to prevent ground moisture from permeating the concrete; good practice provides a gravel base between the earth and the moisture-barrier to assist in moving water away from the slab to avoid upward pressure.

Above-grade slabs (as contrasted with concrete joint floors) must be reinforced. The slab can be considered structurally as a continuous series of beams, each bending under load creating tensile stresses on the lower side. Since concrete has compressive strength but low tensile strength, steel reinforcing is used to provide the tensile requirements. Significant cracks in such floors might indicate either that at some time the loading on the slab exceeded the capacity or that formwork used to support the slab during construction may have been prematurely removed (before the concrete had attained adequate strength and before the steel and concrete had adequately bonded). Minor cracks may result from expansion or contraction, or from stresses during curing. Reinforcing must be located within the concrete; exposed reinforcing not only permits corrosion of the steel (weakening its capacity) but also indicates probable lower structural capability, and a heightened risk of structural failure in the event of fire due to lack of protection from heat.

Framed Floors

Framed floors are in effect composite, one component serving as the primary structural element, the other providing the surface of the space above (Figure 3-13). The surface element may have a secondary structural function, that of bracing the structural element or of distributing the load to several structural units so that the floor acts as a panel.

Materials used are wood, steel, or concrete, or combinations. Wood floors may be either joist-and-subfloor or plank-and-beam. Steel framing may be either beams or bar-joists, in either case generally supporting a concrete slab (frequently on steel deck). Concrete may be pre-cast or cast-in-place, or tee or waffle pattern.

Wood joist floor construction consists at least of sill plates, beams, joists, and subfloor. Joists serve as the major structural element of the floor, with the subfloor bracing the joists and serving as a basis for the installation of the final floor. For first floors, the sill plate should be anchored to the foundation to provide stability, and to provide support and fastening for the joists. In platform framing (Figure 3-14a), a header of the same depth as the joists is used to provide endbracing for the joists, and the area available for joistbearing is reduced by the thickness of the header. In balloon framing (Figure 3-15a), the studs of the wall framing are fastened to both the sill plate and the joists, and no header is needed since the studs provide end-bracing for the joists.

Floor joists are selected primarily to meet strength and stiffness requirements. The strength requirements are determined by the loads to be carried, species and grade of wood, spacing, and the length of span, or the distance between points of support. Stiffness requirements, established by the need to limit deflection, also limit vibration due to moving loads. Table 3-2 indicates spans for typical species and grades of lumber.

Floor joists, generally of two inch nominal thickness lumber and 8, 10, or 12 inch nominal depth, span the exterior walls and intermediate supports, which may be either beams (or girders) on posts (or piers) or bearing partitions.

Upper story floor joists in platform construction rest on the plate (normally double) at the top of the wall framing along with the header (Figure 3-15b). In balloon frame construction, upper floor joists rest on a ledger strip fastened to the face of the wall framing, and are nailed to the sides of the studs (Figure 3-15b).

If the floor joists are deeper than 12 inches, bridging or blocking must be installed at intervals no greater than 8 feet.

In masonary construction, wood floor joists must be supported by the masonry in such a way that, in the event of fire, the joists are released and do not cause the wall to collapse (Figure 3-16a). For the first floor, the foundation wall can be thickened (Figure 3-16b), and on upper floors the masonry can be corbelled (Figure 3-16c), or a ledger can be anchored to the wall below the joists (Figure 3-16d) or notched joists can set into a notch in the wall (Figure 3-16a).

The subfloor braces the joists, and also provides a base for the finishing flooring (Figure 3-15). Plywood has been most generally used in recent years; individual 1" thick boards were used previously, laid perpendicular to the joists or, more frequently, laid diagonally across the joists. The boards should join tightly, or be tongued-and-grooved together.

Plank-and-beam framing uses thicker lumber, 2 inches or greater, as the subfloor which permits its horizontal supports to be more widely spaced, for example, four to eight feet apart. Such beams, larger in size than individual joists but generally built-up to required size from two inch joists, are supported by the foundation either by setting each in a notch in the foundation (Figure 3-17a) or by using a sill-and-header as in plywood framing (Figure 3-17b). Beams in upper floors may be connected to girders or columns by using connectors similar to those used in heavy timber, or may be a spaced beam straddling the column, with blocking at frequent intervals along the length between the spaced elements of the beam (Figure 3-18).

Heavy timber framing (Figure 2-7) may be constructed using either solid sawn lumber, or glued-laminated members (an assembly of selected 2 inch thick wood layers bonded securely together by adhesives under pressure), with minimum sizes prescribed by the code for Type 3 construction. Six by ten beams are required for floor framing, with the beams supported adequately by walls (Figure 3-19a) or columns (Figure 3-19b). If the beams frame into or onto a masonry wall, self-releasing wall boxes or hangers must be used. In framing into masonry walls, the area of the beam and the area of the masonry used for support (bearing) must each be adequate to prevent greater compression or shear than the capacity of the material. If the beam or girder frames into a recess in a masonry wall with a required fire rating, at least 4 inches of masonry must exist between beams on opposite sides, or between the beam and the outside face of the wall. Beams and girders should not penetrate through the wall.

No concealed spaces are permitted in the floor, which must be at least three inches thick, with finished floor above it of one inch tongue-and-groove strips. The floor deck must be free of masonry walls by one-half inch to provide an expansion joint. In some cases, cast iron or steel columns may have been used; under Type 3, these materials must have one-hour fire rated protection. Floors framed of concrete (Figure 3-20a) and/or steel (Figure 3-20b) are non-combustible.

Finish Flooring

The term "finish flooring" refers to the material used as the final wearing surface that is applied to a floor. Perhaps in its simplest form it might be paint over a concrete floor slab.

Numerous flooring material now available may be used over a variety of floor systems. Each has a property that adapts it to a particular usage. Of the practical properties, perhaps durability and maintenance ease are the most important. However, initial cost, comfort, and beauty or appearance must also be considered. Specific service requirements may call for special properties, such as resistance to hard wear in warehouses and on loading platforms, or comfort to users in offices and shops.

There is a wide selection of wood materials that may be used for flooring. Hardwoods and softwoods are available as strip flooring in a variety of widths and thicknesses and as random-width planks and block flooring. Other materials have included linoleum, asphalt, rubber, cork, vinyl, and other resilient materials in tile or sheet forms. Ceramic tile, brick, quarry tile, stones, and carpeting are used in many areas.

Softwood finish flooring costs less than hardwood species and is often used to good advantage in bedroom and closet areas where traffic is light. It might also be selected to fit the interior decor. It is less dense than the hardwoods, less wear-resistant, and shows surface abrasions more readily. Softwoods most commonly used for flooring are southern pine, Douglas fir, redwood, and western hemlock.

Hardwoods most commonly used for flooring are red and white oak, beech, birch, maple, and pecan. Manufacturers supply both prefinished and unfinished flooring.

Strip flooring is normally laid length-wise in a room at right angles to the floor joists (Figure 3-21a). This is desirable appearance-wise and also reduces shrinkage and swelling effects on the flooring during seasonal changes. Some type of subfloor of diagonal boards or plywood is normally used under the finish floor. Strip flooring of this type is tongued-and-grooved and end-matched. Strips are random length and may vary from 2 to 16 feet or more. End-matched strip flooring 25/32-inch thickness is generally hollow backed (Figure 3-21b). The face is slightly wider than the bottom so that tight joints result when flooring is laid. The tongue fits tightly into the groove to prevent movement and floor "squeaks."

Floor squeaks are usually caused by movement of one board against another. Such movement may occur because: (a) floor joists are too light, causing excessive deflection, (b) sleepers over concrete slabs are not held down tightly, (c) tongues are loose fitting, or (d) nailing is poor. Adequate nailing is an important means of minimizing squeaks.

The finish floors should be installed after the joists have dried to 12 percent moisture content or less, and nailed through the subfloor into the joists rather than only to the subfloor.

Wood block floors, with end grain exposed, were widely used for industrial-type uses; treatment with creosote provided protection against decay, moisture, mold, and insects.

Resilient floors and carpet should not be installed directly over a board or plank subfloor. Underlayment grade of wood-based panels such as plywood, particleboard, and hardboard is widely use for suspended floor applications. However, particleboard is not approved for use as subfloor.

Concrete for resilient floors should be prepared with a good vapor barrier installed between the soil and the finish floor, preferably just under the slab. Concrete should be leveled carefully when a resilient floor is to be used directly on the slab to minimize dips and waves. Tile should not be laid on a concrete slab until it has completely dried.

Linoleum, widely used in earlier years, is no longer manufactured in the United States and if needed for rehabilitation, must be imported from Europe.

It is generally impossible to fill in replacement-tiles in asphalt, vinyl, vinyl-asbestos, or rubber tiles, since colors and patterns change, and the maintenance of the existing floor over the years has resulted in other changes.

The advantages of carpeting in sound absorption, thermal insulation and resistance to impact should be considered. This is particularly important in multi-floor apartments where impact noise reduction is an extremely important phase of construction. If carpeting is to be used, subfloor can consist of ⅝-inch (minimum) tongued and grooved plywood (over 16-inch joist spacing).

Ceramic tile, quarry tile, slate, flagstone, and similar floor coverings in many sizes and patterns for bath, lavatory, entry areas may be installed by the cement-plaster method or by the use of adhesives. The cement-plaster method requires a concrete-cement setting of 1¼ inches minimum thickness (Figure 3-22). Joists are chamfered (beveled) and cleats used to support waterproof plywood subfloor or forms cut between joints. The cement base is reinforced with woven wire fabric or expanded metal lath.

The floor surface in bathrooms and kitchens must be constructed and maintained to be impervious to water, and permit being kept in a clean and sanitary condition.

WALLS

As discussed earlier, walls serve two functions: structural support, and separation of spaces. These two functions may be combined in one surface, as in bearing walls; or differentiated with the structural function handled by columns and beams, and the wall being a non-bearing separating surface. Either approach is used both on the exterior and interior. The visual appearance of both the combined or differentiated types may be the same (as in many historical styles) or the differentiated construction may look different (as in some historical and many contemporary styles). Similarly, because of the nature of the materials used, both bearing and non-bearing walls frequently use the same techniques of construction.

Separation of spaces between the exterior and interior of the building serves to provide a barrier against weather; to control the flow of air, moisture, heat, and water vapor; to provide privacy in terms of sight and sound; and to provide fire-resistance to contain a fire in the area of origin and prevent its spread to adjacent areas or buildings.

In addition to its structural function of transmitting loads vertically from other elements of the building, and its separating function, a wall also provides desired appearance characteristics and accommodation of portions of the heating, air-conditioning, electrical, and plumbing systems. In most cases, the wall is also the principal location for openings and other penetrations for light, ventilation, and movement, and means must be provided for supporting windows, doors, grilles, and other such units.

The finished appearance of the wall may be determined by the nature of the construction used to meet the structural or separating requirements, as well as by the type or placement of the penetrations. However, the materials used may be chosen for their appearance, and the construction modified accordingly; for example, use of massive masonry produces a greater structural load due to its weight than lighter-weight framing materials.

Terra cotta, either in normal color ranges or in polychrome, was used in the past many buildings both for wall surfaces and accent detail such as column and pilaster capitals, and molded or curved units were frequently used to provide detailing in wall surfaces.

The major categories of walls are: mass-construction (masonry) and framed (wood, steel, or concrete), each being either bearing or non-bearing. No one wall-assembly is suitable for use for all exposures, conditions of loading, occupancy-type, or locations; however, each may have been so used, and problems of inappropriate use may need to be corrected as part of rehabilitation.

Mass Walls

Walls of mass construction may be built of unit-masonry (brick, clay tile, concrete block or adobe), of concrete (plain or reinforced), or a combination of several of these.

Brick used as a veneer over woodframed structure is discussed under wall finishes later. Masonry walls may be solid, acting as a unit to support loads, with the individual units (either solid or hollow) laid close together and the joints between filled with mortar; or these may be hollow, with the walls intentionally separated into inner and outer surfaces, of solid or hollow units laid in a similar way as solid walls in each surface.

Metal ties or joint reinforcements (Figure 3-23) are used in solid walls of brick, clay tile, and concrete for structural bonding between adjacent vertical sections of masonry walls. Many of the patterns in which brick is laid (the different bonds (Figure 3-24)) result from earlier usage of masonry headers to bond the wythes, which allows greater penetration by rain. Staggering the wythes by overlapping alternate courses provides masonry bonding.

Hollow walls of masonry (Figure 3-25) generally have two wythes of masonry separated by a space. The wythes need not be the same thickness. In cavity walls, the space may be 2 inches to 4 inches in width, and metal ties or reinforcement must be used. The cavity, whether air-space or filled with insulating materials such as perlite or vermiculite, provides greater resistance to heat flow than the masonry alone and acts as a barrier to the inward movement of moisture. Masonry headers would defeat both purposes. The cavity must be clean of mortar, and weep holes with adequate flashing must be made available through the joints of the lower courses to allow moisture penetrating the outer wythe to drain out.

The thickness of masonry walls determines the allowable height or length between supporting or bracing units (such as columns, piers, cross-walls, etc.) for the types of construction discussed so far (Table 3-3). Building tall buildings with solid masonry walls became illogical because of increasing thickness of walls, as well as the increasing weight of the walls above. The first solution for tall buildings was to use cast iron or steel columns for the structural portion. A more recent solution has been to use reinforced masonry (Figure 3-26), in which steel reinforcing as in reinforced concrete, is placed in grout (a strong form of mortar) either in the cells of hollow masonry units or in the cavity of hollow walls.

Problems which develop in masonry walls generally result from inadequate support, penetration of water (leaching the mortar, or freezing, or causing expansion), movement within the wall due to thermal expansion or contraction, stress-concentration over openings, or from restraint by other strutural elements. In addition, in areas subject to seismic forces, the rigidity of masonry construction precludes rapid accommodation of the sudden, intense, and varying forces.

To minimize the effects of the movements due to thermal expansion or contraction and stress-concentration, control joints must be provided at appropriate intervals or locations. (Fig. 3-27). Penetration of moisture can be limited by applying coatings on the outer surface (such as stucco), using appropriate waterproofing materials such as a silicone-based solution, and by use of the proper mortar tooled into the joints. Older mortars frequently were softer and more liable to disintegrate, but most mortars will become cracked, or porous, after a period of time. Walls must be thoroughly inspected to determine the need for tuck-pointing the joints or replacing the deteriorated surface of the mortar. These repairs must be undertaken carefully if visual appearance is critical, as in historical preservation.

Openings in masonry walls, for doors, windows, ventilation, or other large spaces, must be provided by either an arch or some form of lintel (or beam). Due to the arching action of the masonry over the opening (Figure 3-28), the dead weight of masonry only within a triangular area whose height is half the opening width need to be considered. Similarly, concentrated loads (from a floor beam, for example) will be borne primarily by the wall surrounding the opening if the height to the load above the opening is at least 90% of the opening width. For example, if a window is 4 feet wide, a concentrated load should be at least 3 feet 7 inches above; if the head of the window is 7 feet above the floor, the lowest surface of the beam above should be 10 feet 7 inches above the floor.

Two basic types of lintels used are steel structural shapes (angles or beams) and reinforced masonry or concrete units. If steel shapes were used and exposed to weathering, rusting may have occurred and should be checked to determine whether sufficient strength remains to support the loads.

To avoid cracks and leaks, the lintel must be adequate to carry the loads of the triangular area of masonry above the wall plus any concentrated loads lower than the height limit, without producing too great a load on the masonry on each side of the opening on which the lintel rests.

Vertical loads can be supported by masonry columns as well as by walls. Pilasters are columns built into and as part of the wall, while piers are free-standing. The least dimension of a pier must be at least 1/10 its unsupported height; thus, a pier 20 feet high would need to be at least 24 × 24 inches. Pilasters must be no further apart than is required to provide bracing to the wall (Table 3-3) and be at least 1/10 this distance in width.

Framed Walls

Framed construction includes two basic types. In one, such as structural steel or reinforced concrete columns, heavy timber, and post-and-beam, the vertical support elements are structurally independent of the wall surface and widely spaced. In the other, light framing, such as wood, or light-gauge steel or aluminum studs, the vertical support elements are partially independent to the wall-surface which must distribute loads to adjacent members, and are limited in their spacing. Either type may be used for external or internal support.

Light framed walls include vertical members or studs and horizontal members such as sill-or sole plates, top plates, and headers (or lintels) over openings. In platform framing (Figure 3-14) the wall framing extends from the top of one floor surface to the underside of the next. In balloon framing (Figure 3-15) the wall framing extends from the foundation to the roof. The firestopping required by code in all wells and partitions to cut off concealed draft openings between horizontal and vertical sections of the building is provided by the top and bottom plates in platform framing, but must be specificaly installed in balloon framing.

If wood is used for light framing, the construction can be classified only as Type 6 since wood is combustible; light gauge metal framing can be used in any type; depending on circumstances. Wood framing is limited to 3 stories in residential occupancy, lower in other occupancies. Although 2 × 4 wood framing at 16 inch spacing is most common, the code permits 24 inch spacing in one story buildings; 2 × 6 at 24 inch spacing for the lowest floor in two story construction; and requires 2 × 6 members at 16 inch spacing for three story buildings. In interior non-bearing walls, the studs may be set parallel to the wall surface; in all other wall and partitions, the studs must be set perpendicular to the wall surfaces. The spacing of the studs determines the minimum thickness of many of the materials attached to the framing.

The bottom plate in platform construction must be single, the top plates normally must be double. Three studs are necessary at exterior wall corners unless an approved alternative is used (Figure 3-29). Since the connections between studs and plates in a rectangular structure provides neither rigidity nor adequate resistance to lateral forces such as wind, diagonal bracing must be used at each corner unless plywood sheathing is applied over the wall. Other sheathing materials which can be used are diagonal boards, fiberboard, particle board, gypsum panels, or foam insulating sheathing. Sheathing serves as a base for the application of exterior finish, and may reduce the movement of air, water and moisture into the structure.

Headers must be installed over openings in light framed walls to support the loads and the finish materials (Figure 3-30). If the opening does not extend to the floor, a sill serves the same function as a top plate. Headers in the exterior and bearing walls or openings wider than 6 feet need two supporting studs at each end; if under 6 feet, only one supporting stud at each end is needed.

Code provisions cover the number, spacing, and type of fastening for the structural members and wall panels for each type of connection.

The other type of framed construction uses structurally independent columns of cast iron, structural steel, reinforced concrete, or wood, with the wall surface between being non-bearing. Wood members which meet Code requirements as to dimension and connection can be used as Type 3, Heavy Timber; smaller members are classified as post-and beam Type 6, while the third type, pole-framing (Figure 3-31) can be either Type 3 or Type 6 depending on the structural members and assemblies.

Columns in heavy timber construction with a minimum dimension of 8 inches should run continuously vertical, using caps or splice plates of steel or iron, with beams or girders framing into, not onto, the columns. The bearing area of the column must be adequate to prevent compression loads being greater than the capacity of the material.

The Code provisions for these methods of construction are primarily contained in standards, based on good engineering practice, which are referenced in the Code. In general terms these provide that the quality of materials and the design and installation of structural members and their connections for framing ,anchoring, tying and bracing be adequate to develop the strength and rigidity necessary for the purposes intended, and provide the necessary type and degree of fire-protection.

Wall Finishes

EXTERIOR

Many materials are used for the exterior covering of the walls: wood, metal, masonry, asbestos, cement stucco, and plastic, each in a variety of forms, thicknesses, and colors. Some authorities recommend the use of balloon framing for frame buildings over one story if stucco or masonry veneer are used because of differential settlement possible with platform framing which might cause cracks, disconnection, or deformation.

The materials used for the exterior finish must be securely fastened to the underlying structure, and the Code designates the type, spacing, and size of fastenings required for each. Wood veneer panels cannot be used higher than the second story, while brick veneer (Figure 3-32) over wood frame is limited to 20' and must be tied to the framing at prescribed intervals with the Code being more stringent in seismic areas.

Moldings of many types and shapes were used to protect the joints between two surfaces and to reduce the penetration of water into the structural frame at all openings in the wall surface (Figure 3-33). Much of the character of many buildings derives from the design and workmanship of these details whose purpose was the same as that of the code. More recent architectural design, in simplifying or eliminating these details, in some cases reduced the protection provided, especially if the building or its materials were subject to thermal expansion or contraction. The inspector should examine all openings and those locations in the wall surfaces where materials or direction changed for cracks or holes permitting air, moisture, water, or vermin to enter.

The Housing Code requires that all exterior wood surfaces, if not of decay-resistant species, be protected from the weather and decay by painting or using other protective treatment. All siding must be weather-resistant and water tight, and masonry joints must be adequately tuck-pointed to insure water and air tightness. Every exterior wall must be free of holes, breaks, loose or rotting boards, and any other conditions which might admit rain or dampness to the interior portion of the wall or to the interior of the building.

Peeled or worn paint on wood siding will expose the bare wood to the elements and result in splitting and warping of siding. This condition will eventually lead to the entrance of rain water with resultant rotting of the sheathing and studs as well as inside dampness and falling plaster. Sound and painted siding will prevent major repairs and expenses in the future. Breaks in the paint surface may be caused by the movement of water vapor from the interior of the building through the wall construction; in cold weather, the water vapor may condense between the paint and the siding, causing the paint to separate and probably break. A vapor barrier, not required by any code other than energy conservation provisions for new construction, is in most climates the simplest method of preventing this problem. The vapor barrier also reduces the possibility of water vapor entering the framing space, condensing, and dropping to the plate, possibly inducing dry rot. Good caulking at all cracks and holes helps prevent external water from entering the framing space.

INTERIOR

Interior finish is the material used to cover the interior framed areas or structures of walls and ceilings. It may be prefinished, or serve as a base for paint or other finishes including wallpaper. Depending on whether it is wood, gypsum wallboard or plaster, size and thickness must comply with Code provision. Finishes in bath and kitchen areas have more rigid requirements because of moisture conditions. Several types of interior finishes are used : (a) lath and plaster, (b) wood paneling, fiberboard, or plywood, (c) gypsum wall-board, (d) ceramic tile, and (e) wall coverings of natural or plastic materials.

Though lath and plaster finish is widely used, use of dry-wall materials has increased. Dry wall is often selected because there is usually a time saving in construction. A plaster finish, being a wet material, requires drying time before other interior work can be started; dry-wall finish does not. However, a gypsum dry wall demands a moderately low moisture content of the framing members to prevent "nail-pops." These result when frame members dry out to moisture equilibrium, causing the nailhead to form small "humps" on the surface of the board. Furthermore, stud alignment is more important for single-layer gypsum finish to prevent a wavy, uneven appearance. Thus, there are advantages to both plaster and gypsum dry-wall finishes and each should be considered along with the initial cost and future maintenance involved.

There are many types of dry-wall finishes, but one of the most widely used is gypsum board in 4 × 8 foot sheets and in lengths of up to 16 feet which are used for horizontal application. Plywood, hardboard, fiberboard, particleboard, wood paneling, and similar types, many in prefinished form, are also used.

A plaster finish requires some type of base upon which the plaster is applied. The base must have bonding qualities so that plaster adheres, or is keyed to the base which has been fastened to the framing members.

One of the most common types of plaster base that may be used on sidewalls or ceilings is gypsum lath, (Figure 3-34) which has paper faces with a gypsum filler. This material can be obtained with a foil back that serves as a vapor barrier. If the foil faces an air space, it also has reflective insulating value. Gypsum lath may be obtained with perforations, which, by improving the bond, lengthen the time the plaster remains intact when exposed to fire. Water-resistant gypsum lath is also available.

Wood lath, common years ago, is no longer referred to in the Code nor in the referenced standards and, unlike the other lath materials, is combustible (Figure 3-35). Old wood lath may have dry rot, or have split, or otherwise have become loose from its support.

Metal lath in various forms such as diamond mesh, flat rib, and wire lath is another type of plaster base. It is galvanized or painted to resist rusting. Metal lath is often used as a plaster base around tub recesses and other bath and kitchen areas. It is also used when a ceramic tile is applied over a plastic base. It must be backed with water-resistant sheathing paper over the framing. Some of the rigid foam insulations cemented to masonry walls also serve as a plaster base.

Because some drying usually takes place in wood framing members after a house is completed, some shrinking can be expected; in turn, this may cause plaster cracks to develop around openings and in corners. To minimize, if not eliminate, this cracking, expanded metal lath is used in certain key positions over the plasterbase material as reinforcement. Strips of expanded metal lath may be used over window and door openings.

Masonry walls may be plastered directly, or lath may be furred from the masonry surface, using wood or metal strips; metal lath is available with furring included.

Plaster for interior finishing is made from combinations of sand, lime, or prepared plaster and water. Waterproof-finish wall materials (Keene's cement) are available and should be used in bathrooms, especially in showers or tub recesses when tile is not used.

Plaster should be applied in three-coat or two-coat work. The minimum thickness over ⅜-inch gypsum lath should be about ½ inch. The first plaster coat over metal lath is called the scratch coat and is scratched, after a slight set has occurred, to insure a good bond for the second coat. The second coat is called the brown or leveling coat, and leveling is done during the application of this coat.

Two-coat work, combining the scratch and brown coat, is used on gypsum lath, and leveling and plumbing of walls and ceilings are done during application.

The final or finish coat consists of two general types—the sand-float and the putty finish. In the sand-float finish, lime is mixed with sand and results in a textured finish, the texture depending on the coarseness of the sand used. Putty finish is used without sand and has a smooth finish where a gloss paint or enamel finish is used. Keene's cement is often used as a finish plaster in bathrooms because of its durability.

The plastering operation should not be done in freezing weather without constant heat for protection from freezing. In normal construction, the heating unit is in place before plastering is started.

Insulating Plaster, consisting of a vermiculite, perlite, or other aggregate with the plaster mix, may also be used for wall and ceiling finishes.

The use of thin sheet materials such as gypsum board or plywood requires that studs and ceiling joists have good alignment to provide a smooth, even surface. Sheathing may correct misaligned studs on exterior walls.

Gypsum board and the other dry wall materials normally are fastened directly to framing members, although several forms of resilient chips are available to reduce acoustic transmission. Furring may be used on masonry walls to allow fastening, although foam insulation may be fastened to both masonry and the dry wall panel with adhesive (Figure 3-36). Type, number, and spacing of fastening or attachment points are set forth in the Code.

The nature of the interior finish has two other Code concerns: fire-protection, and flame spread and smoke development. The materials used for the interior surface may have fire-protection as a characteristic and also as a requirement, by virtue of their location, or type of construction, or occupancy. Refer to Chapter V.

ROOFS

The roof of a building in most cases serves primarily as an enclosing surface between the interior and exterior, and is not used as a working surface. Its structural loads result from external forces (wind, rain, snow, sun, etc.), or from the weight of any equipment (air-conditioning, solar collectors, signs, etc.). As an external surface of the building, it may be required to have a fire-resistance rating to prevent the spread of fire to or from adjacent buildings. As indicated in Chapter I, the nature of the roof may be a significant feature of the building's appearance and character.

Like the wall, the roof should provide a barrier against weather, and control the flow of air, moisture, heat and water vapor, and sometimes light. Thermal expansion and contraction can be a problem for the connections and durability of the materials used, since solar radiation is a major factor. In areas subject to high winds or hurricanes, anchorage of the roof construction to the wall becomes critical in order to prevent uplift, a reversed loading from that normally occurring.

Roofs must be structurally sound and maintained in a safe manner, with no defects to admit rain or cause dampness in the walls or inside the building. Although penetrations through the roof are generally far less numerous or extensive than in walls, their relationship to the roof surface is more critical in terms of preventing the movement of water and air to the interior of the building, and less critical generally in terms of transmitting structural loads.

Roofs may be classified in three types, based on the relationship of the roof surface to the ceiling surface (Figure 3-37 a,b,c):

(a), those in which the roof surface and the ceiling are opposite faces with the structure in between;

(b), those in which the structural elements separating these two surfaces lie within an attic space; and

(c), those in which the structural elements are located under a deck, the underside of which is exposed as the ceiling.

The shape of the roof (Figure 3-38) may be flat, sloping, or arched. It may slope in one direction (a shed roof), in two directions (gable roof), or four (hip roof), or a combination of sloping and flat (Mansard roof), or of two slopes (gambrel roof). If arched, it may extend in one direction (vault) or be rotated (dome). Flat or sloping roofs may be contained within an extended wall (parapet), may overhang the wall, or may terminate at the outer edge of the wall. Each of these conditions of shape and extent contains different problems, and different solutions to the problems of roofs.

The majority of roofs are of frame construction, regardless of their shape; arched roofs (vaults or dome) or mass construction use masonry or reinforced concrete. Wood, steel and reinforced concrete predominate as the materials used for the framing and the decking, with some use of aluminum. The spacing of the roof framing components affects the nature of the supporting wall structure but is not necessarily determined by the wall structure. Beams, joists and rafters, and trusses are the types of framing components generally used, either as light framing with relatively close spacing, or more widely spaced at the same intervals as the columns or piers which provide support.

Joist-and-rafter systems in wood consist of nominal 2 inch lumber ceiling joist and roof rafters spaced 12 inches, 16 inches or 24 inches o.c. Typical construction for joist-and-rafter roofs is shown in Figure 3-39. Joists span roughly one-half the width of the building from the exterior walls to a center bearing wall, beam, or girder. The rafters are supported on exterior walls and bear against each other and/or a ridge board at the high point of the roof. When loaded, the ridge tends to lower and the rafters exert a thrusting force which tends to spread the outside walls. This thrust is resisted by the ceiling joists acting as ties from wall to wall, and/or by collar beams.

The sizes of the joists and rafters depend on the span, wood species, spacing between joists, and the loads. The correct sizes for various conditions can be found in joist tables referenced in the Building Code; spans for typical species and grades of lumber are indicated in Table 3-4.

The span may be reduced by installing purlins (minor beams) and braces between the rafters and the joists and bearing partitions.

Interior bearing walls somewhat restrict the flexibility of room planning. Joist-and-rafter systems provide overhead space for the installation of insulation and mechanical equipment; and in addition, with adequate rafter slopes, economical attic storage or expansion space can result.

Trusses are composed of a number of framing members arranged in a framework of triangles to form a supporting structural element for a roof. Individual wood members are connected by wood or metal connectors, and in metal by bolts, rivets, or welding, either directly or using auxiliary shapes. The truss acts as a unit to support roof loads, and spans greater widths than permitted for other framing systems. This clear span allows interior walls to be non-load bearing and permits almost complete flexibility in placing or eliminating walls.

Because of the structural action within a truss, individual members primarily resist compression and tension forces. Bending stresses are relatively small; hence, truss members may be considerably smaller than their counterparts in joist-and-rafter systems which resist bending forces primarily. Trusses require stress-rated members and must be built from engineered designs. In light framing (especially in wood), they commonly are spaced from 24 inches to 48 inches o.c.

Truss roof systems may be designed for flat or sloped roofs to receive membrane or shingle roofing finishes.

The systems provide overhead space for the installation of insulation and heating, air conditioning, electrical and plumbing equipment.

Trusses commonly used include King-post, W-type, and scissors.

The King-post is the simplest form of truss used, as it is composed only of upper and lower chords and a center vertical post (Figure 3-40a). Allowable spans are somewhat less than for the W-truss when the same size members are used, because of the unsupported length of the upper chord.

The W-type truss (Figure 3-40b) is perhaps the most popular and extensively used of the light trusses. Its design includes the use of more members than the King-post truss, but distances between connections are less.

The Scissors truss (Figure 3-40c) is a special type used when a sloping ceiling is desired or if greater clearance is necessary under the center, but is more complicated than the W-type truss.

Bar joists are one form of steel truss, generally with the lower chord parallel to the top chord.

In roof framing construction, with greater distances between trusses and greater loads, the members of the truss become heavier. In roof framing for heavy timber construction framing members must have minimum dimensions of 4 × 6 inches, or if sprinklered, 3 × 6 inches.

In joist roof/ceiling systems, the functions of ceiling joists and roof rafters are provided for by roof joists alone (Figure 3-41). These joist members generally are of nominal 2 inch dimension lumber or of steel bar joists spaced 12 inches, 16 inches or 24 inches o.c. Joists may have a clear span between exterior walls or be supported on bearing partitions or structural beams when the roof is sloped rather than flat; the construction also may be called a ridge-supported rafter system which often is used to achieve an interior sloped ceiling effect.

Ductwork can be accommodated in joist space if run parallel to the joists. When it is necessary to run ductwork perpendicular to the joists, it is common to use dropped-ceiling areas. Bar joists permit ductwork running in either direction. Wiring can be concealed in the joist space and the system is relatively easy to insulate.

In beam-and-girder systems, the structural framing is generally below the decking surface. The size and spacing of the framing members is determined by the type and characteristics of the decking. In wood, the system is generally known as plank-and-beam in its lighter form. As the framing members become greater in dimension the name changes to either post and beam or heavy timber framing; the dimensions used are 6 × 6 and larger.

Plank-and-beam roofs typically are used on one-story buildings and for lowslope and flat roofs. These systems are characterized by the use of 2″ × 6″ or 2″ × 8″ tongue-and-grooved (T&G) or splined planks spanning between either longitudinal or transverse beams (Figure 3-42). Nominal 2 inch plank generally may be used on spans up to approximately 8 feet.

Longitudinal beams span parallel to the long dimension of the building and are supported on end walls or columns. In buildings up to approximately 36 feet wide, the beams typically are placed at quarter points. This divides the width of the building into two equal spans for planking on each side of the center ridge beam. Planks may be supported along the exterior sides by walls or beams. Interior planning flexibility is slightly more restricted than when traverse beams are used because of the greater number of beams supports required.

Traverse beams, generally spaced 4 feet to 8 feet o.c., span perpendicular to the long dimension of the building and may be supported by bearing walls and/or beams along the ridge or center of the building. The transverse beam system may be used with wood stud exterior walls and is often used with post-and-beam exterior walls (Figure 3-43).

The plank ceiling and roof deck does not provide overhead space for the convenient concealment of ductwork and wiring. If the system requires insulation, it may be applied to the top of the deck, which in turn may limit the selection of roofing finishes.

Plank-and-beam systems, in contrast to truss and joist-and-rafter roof systems, require different design and construction methods and care in erection, since the finished appearance generally is an integral part of the system. The planks, beams and columns generally are left exposed as the finished interior surface.

Heavy timber beams, joists, or glued-laminated arches have similar requirements as in floor framing, with sizes the same as those for trusses.

Steel and reinforced concrete roof beams and girders are designed and installed similarly to floor systems.

Decking or sheathing for the above systems provides the structural surface of the roof.

Roof sheathing is the covering over the rafters or trusses, and usually consists of nominal 1-inch lumber, or plywood. In some types of flat or low-pitched roofs with post and beam construction, wood roof planking or fiberboard roof decking might be used. Diagonal wood sheathing on flat or low-pitched roofs provides cracking resistance where areas with high winds demand added rigidity. Plywood sheathing provides the same desired rigidity and bracing effect. Sheathing should be thick enough to span between supports and provide a solid base for fastening the roofing material.

Board sheathing to be used under such roofing as asphalt shingles, metal-sheet roofing, or other materials that require continuous support should be laid closed (without spacing) (Figure 3-44). Wood shingles can also be used over such sheathing. Boards should be matched, shiplapped, or square-edged with joints made over the center of rafters. Not more than two adjacent boards should have joints over the same support. It is preferable to use boards no wider than 6 to 8 inches to minimize problems which can be caused by shrinkage. Boards should have a minimum thickness required for rafter spacing, and be fastened as required. End-matched tongued-and-grooved boards can also be used and joints may occur between rafters. However, in no case should the joints of adjoining boards be made over the same rafter space. Each board should be supported by at least two rafters.

When wood shingles or shakes are used in damp climates, it is common to have spaced roof boards (Figure 3-45). Wood nailing strips in nominal 1 × 3 or 1 × 4 inch size are spaced the same distance on centers as the shingles, to provide the needed ventilation spaces.

When plywood roof sheathing is used, it should be laid with the face grain perpendicular to the rafters (Figure 3-46). Standard sheathing grade plywood is commonly specified but, where damp conditions occur, it is desirable to use a standard sheathing grade with exterior glueline. End joints are made over the center of the rafters and should be staggered by at least one rafter. Edge joints should be supported by blocking between the joists or rafters, or with the use of plyclips or similar H clips between rafters instead of blocking.

Plank roof decking, consisting of 2-inch and thicker tongued-and-grooved wood planking, is commonly used in flat or pitched roofs in post-and-beam construction and in heavy timber framing. Common sizes are nominal 2 × 3, 3 × 6, and 4 × 6-inch V-grooved members. Roof decking can serve both as an interior ceiling finish and as a base for roofing. Heat loss is greatly reduced by adding rigid insulation over the wood decking.

A vapor barrier is ordinarily installed between the top of the plank and the roof insulation when planking does not provide sufficient insulation.

Fiberboard roof decking is used the same way as wood decking, except that supports are spaced much closer together. Planking is usually supplied in 2 × 8 foot sheets with tongued-and-grooved edges. Decking used for steel and concrete framing is similar to those used for floor slabs.

The selection of the roof finish materials has an effect on the spacing, span, and slope of the structural components, on the nature of the sheathing or decking used, and on the adequacy of the construction. Roof coverings should provide a long-lived waterproof finish that will protect the building and its contents from rain, snow, and wind. Many materials have withstood the test of time and have proved satisfactory under given service conditions.

Materials used for pitched roofs are wood, asphalt, and asbestos shingles, and also tile and slate. Sheet materials such as roll roofing, galvanized iron, aluminum, copper, and tin are also used. Perhaps the most common covering for flat or low-pitched roofs is the built-up roof with a gravel topping or cap sheet. Plastic films, often backed with an asbestos sheet, are also being applied on low slope roofs.

Roof underlay material usually consists of 15 or 30-pound asphalt-saturated felt and should be used in moderate and lower slope roofs covered with asphalt asbestos, or slate shingles, or tile roofing. It is not commonly used for wood shingles or shakes. In areas where moderate to severe snowfalls occur, cornices without proper protection will often be plagued with ice dams. These are formed when snow melts, runs down the roof, and freezes at the colder cornice area. Gradually, the ice forms a dam that backs up water under the shingles. Under these conditions, it is good practice to use an undercourse (36-inch width) of 45-pound or heavier smooth-surface roll roofing along the eave line as a flashing (Figure 3-47). This will minimize the chance of water backing up and entering the wall. However, good attic ventilation and sufficient ceiling insulation are of primary importance in eliminating this harmful nuisance.

In shingle application, the exposure distance is important and the amount of exposure generally depends on the roof slope and the type of material used. This may vary from a 5-inch exposure for standard size asphalt and wood shingles on a moderately steep slope to about 3½ inches for flatter slopes. However, asphalt shingles with double underlay and triple shingle coverage can be used for flatter slopes. coverage.

The usual minimum recommended weight for asphalt shingles is 235 pounds for square-butt strip shingles. This may change in later years, as 210 pounds (weight per square) was considered a minimum several years ago. Strip shingles with a 300-pound weight per square are available, as are lock-type and other shingles weighing 250 pounds and more. Asphalt shingles are also available with seal-type tabs for wind resistance. Many contractors apply a small spot of asphalt roof cement under each tab after installation of regular asphalt shingles to provide similar protection.

The first course of asphalt shingles is doubled; or, a starter course may be used under the first asphalt-shingle course, or a course of wood shingles or a metal edging along the eave line before application of the asphalt shingles. (Figure 3-45).

The principle damage to asphalt shingle roofs is caused by the action of strong winds on shingles nailed too high. Usually the shingles affected by winds are those in the four or five courses nearest the ridge and in the area extending about 5 feet down from the edge or rake of the roof.

Wood shingles of the types commonly used for roofs are No. 1 grade, all-heartwood, all-edgegrain, and tapered. Western red cedar and redwood are the principal commercial shingle woods, as their heartwood has high decay resistance and low shrinkage.

The most important factors of this type roofing are its pitch and exposure, the character of wood, kind of nails used, and preservative treatment given shingles. Creosote and coal tar preservative are satisfactory for both treated and untreated shingles.

Even though wood shingles and shakes can be fire-retardancy-treated, they are considered more combustible than the other types. Generally, they can not be used in fire districts, and are banned in many jurisdictions in all areas, even though they are included in the Code but do not have a fire-resistive rating.

Other types of roofing shingles and tiles, such as slate, asbestos-cement (mineral-fiber), concrete or clay tiles, must be installed in accordance with the standards referenced in the Code.

The most common problem with slate roofs is the replacement of broken slates. Roofs of this type normally render long service with little or no repair.

Replacement of broken shingle tiles is the main maintenance problem with tile roofs. This is one of the most expensive roofing materials. It requires very little maintenance and gives long service.

Built-up construction is used mainly for flat or low-pitched roofs but can be adapted to steeper slopes by the use of special materials and methods

Built-up roof coverings may have 3, 4, or 5 layers of roofer's felt, each mopped down with tar or asphalt, with the final surface coated with asphalt and covered with gravel embedded in asphalt or tar, or covered with a cap sheet. For convenience, it is customary to refer to built-up roofs as 10-, 15-, or 20-year roofs, depending upon the method of application.

For example, a 15-year roof over a wood deck (Figure 3-48) may have a base layer of 30-pound saturated roofer's felt laid dry, with edges lapped and held down with roofing nails. The dry sheet is intended to prevent tar or asphalt from entering the rafter spaces. Three layers of 15-pound saturated felt follow, each of which is mopped on with hot tar rather than being nailed. The final coat of tar or asphalt may be coverd with roofing gravel or a cap sheet of roll roofing.

The cornice or eave line of projecting roofs is usually finished with metal edging or flashing, which acts as a drip. A metal gravel strip is used in conjunction with the flashing at the eaves when the roof is covered with gravel. Where built-up roofing is finished against another wall, the roofing is turned up on the wall sheathing over a cant strip and is often also flashed with metal. This flashing is generally extended up about 4 inches above the bottom of the siding.

Asphalt built-up roofs may be unsurfaced, the coating of bitumen being exposed directly to the weather, or they may be surfaced having slag or gravel imbedded in the bituminous coating. The use of surfacing material is desirable as a protection against wind damage and elements. This type of roof should have enough pitch to drain water readily.

Coal tar/pitch built-up roofs must be surfaced with slag or gravel. Coal tar/pitch built-up roofs should always be used on deck pitched less than ½ inch per foot; that is, where water may collect and stand. This type of roof should be inspected on completion, six months later, and then at least once a year, preferably in the fall. When the top coating of bitumen shows damage or has become badly weatherized, it should be renewed.

Metal roofs (tin, copper, galvanized iron, or aluminum) are also used. Joints should be watertight and the deck properly flashed at the juncture with the house. Nails should be of the same metal as that used on the roof, except that with tin roofs, steel nails may be used. All exposed nailheads in tin roofs should be soldered with a rosin-core solder.

Copper roofs usually are of 16-ounce copper sheeting and applied to permanent structures. When properly installed, they require practically no maintenance or repair. Proper installation allows for expansion and contraction with changes in temperature.

With galvanized iron roofs, maintenance is done principally by removing rust and keeping the roof well painted. Leaks can be corrected by renailing, caulking, or replacing all or part of the sheet or sheets in disrepair.

The other surface involved in a roof/ceiling system is the ceiling. The plaster and dry wall materials discussed under wall finishes are used for ceilings, normally applied to the underside of the framing system, but may be suspended at the a lower height using secondary framing at the required intervals. Other materials are also used, most frequently having sound-adsorbing charactestics, and generally but not necessarily suspended from the framing above. With these materials, the supporting grid may be exposed, allowing the ceiling tiles to be removed, or it may be concealed by the ceiling materials. The materials used are glass-and-mineral-fiber and vegetable fiber tiles, or perforated metal tiles, or sheets with fiber pads above. The suspended ceilings permit maintenance and repair of piping, conduits, and ductwork or equipment mounted from the framing above the ceiling, but also permit leaks from the surface above to remain hidden.

If the roof or floor system is required to have a fire resistive rating, the ceiling membrane used is part of the assembly tested.

Penetrations through the roof system include vents for the plumbing and heating systems, chimneys, skylights, and dormers. Adequate construction and flashing (see Chapter IV) must be provided to prevent leakage. Skylights must be provided with screening to prevent the glazing from being broken and falling into the interior of the building.

If the roof of the structure appears to be sagging, the inspector should make a special effort to examine the rafters, purlin, collar, beams, and ridge boards if these members are exposed, as in unfinished attics. The condition of the roof boards may be examined while the inspector is in the attic. If light can be seen between these boards the roof is unsound. Evidence of a leaking roof will be indicated by loose plaster or peeling or stained paint and wallpaper. Areas of the roof where flashing occurs, such as around the chimney, are frequent origins of roof leaks. It is essential that the leak be found and repaired, not only to prevent the entrance of moisture into the building, but also to prevent the loosening of the plaster, rotting of timbers, and extension of damage to the remainder of the building.

Roof chimneys should be inspected for tilting, missing bricks, deterioration of flashing, and pointing of chimney bricks. In addition, roof coverings should be checked for broken spots and missing shingles or tiles. Roof doors should be metal clad, self-closing, tight fitting, and unlockable.

Material Type	Height of Unbalanced Fill in Feet	Length of Wall Between Supporting Masonry or Concrete Walls in Feet	Minimum Wall Thickness in Inches
Hollow Masonry	4 or less	unlimited	8
	more than 4	design required	design required
Concrete or Solid Masonry	4 or less	unlimited	8
	more than 4	less than 8	8
	8 or less	8 to 10	8
		10 to 12	8
	more than 8	design required	design required

TABLE 3-1

MATERIAL	HEIGHT or LENGTH
Stone	14 × t
Cavity and[3] Hallow Units	18 × t
Solid and Grouted (plain)	20 × t
Reinforced Grouted	25 × t

TABLE 3-3

ALLOWABLE SPANS FOR FLOOR JOISTS

Spans are based on Repetitive Member Values for Normal Duration of Loading. The allowable span is the clear distance between supports.

		All rooms used for sleeping areas and attic floors: **Liveload 30 lb./sq. ft.** **Deadload 10 lb./sq. ft. Deflection—1/360th of span**											**All rooms except those used for sleeping areas and attic floors:** **Liveload 40 lb./sq. ft.** **Deadload 10 lb./sq. ft. Deflection—1/360th of span**										
		Maximum Allowable Spans in Feet and Inches											*Maximum Allowable Spans in Feet and Inches*										
Size in	*Spacing in*	*Southern Pine*					*Douglas Fir-Larch*		*Hem-Fir*		*Spruce-Pine-Fir*		*Southern Pine*					*Douglas Fir-Larch*		*Hem-Fir*		*Spruce-Pine-Fir*	
Inches	*Inches*	*No. 1 KD*	*No. 2MG KD*	*No. 2MG*	*No. 2 KD*	*No. 3 KD*	*No. 2*	*No. 3*	*No. 2*	*No. 3*	*No. 2*	*No. 3*	*No. 1 KD*	*No. 2MG KD*	*No. 2MG*	*No. 2 KD*	*No. 3 KD*	*No. 2*	*No. 3*	*No. 2*	*No. 3*	*No. 2*	*No. 3*
2 × 6	12	12-6	12-0	11-10	11-7	10-9	12-0	10-4	11-3	9-3	11-0	8-6	11-4	10-11	10-9	10-6	9-9	10-11	9-3	10-3	8-3	10-0	7-7
	16	11-4	10-11	10-0	10-6	9-4	10-11	9-0	10-3	8-0	9-9	7-4	10-4	9-11	9-9	9-6	8-4	9-11	8-0	9-4	7-2	8-8	6-7
	24	9-11	9-7	9-4	9-0	7-7	9-7	7-4	8-6	6-6	7-11	6-0	9-0	8-8	8-6	8-1	6-9	8-7	6-7	7-7	5-10	7-1	5-5
2 × 8	12	16-6	15-10	15-7	15-3	14-4	15-10	13-8	14-11	12-2	14-6	11-3	15-0	14-5	14-2	13-10	12-8	14-5	12-2	13-6	10-10	13-2	10-0
	16	15-0	14-5	14-2	13-10	12-3	14-5	11-10	13-6	10-6	12-10	9-9	13-7	13-1	12-10	12-7	11-0	13-1	10-7	12-3	9-5	11-6	8-8
	24	13-1	12-7	12-4	11-11	10-0	12-7	9-8	11-3	8-7	10-6	7-11	11-11	11-5	11-3	10-8	9-0	11-3	8-8	10-0	7-8	9-4	7-1
2 × 10	12	21-0	20-3	19-10	19-5	18-1	20-3	17-5	19-0	15-6	18-6	14-4	19-1	18-5	18-0	17-8	16-3	18-5	15-7	17-3	13-10	16-10	12-10
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	24	16-8	16-1	15-9	15-3	12-9	16-1	12-4	14-4	11-0	13-4	10-1	15-2	14-7	14-4	13-7	11-5	14-5	11-0	12-10	9-10	11-11	9-1
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	16	23-3	22-5	21-11	21-6	19-1	22-5	18-4	21-0	16-4	19-11	15-1	21-1	20-4	19-11	19-6	17-0	20-4	16-5	19-1	14-7	17-9	13-6
	24	20-3	19-7	19-2	18-6	15-7	19-7	15-0	17-5	13-4	16-3	12-4	18-5	17-9	17-5	16-6	13-11	17-6	13-5	15-7	11-11	14-6	11-0

NOTE: The Grademark that is required on each piece of material provides the species of lumber and its grade. For Species and Grades other than those covered by the above table, refer to the "Span Tables for Joists and Rafters" as published by the National Forest Products Association.

TABLE 3-2

ALLOWABLE SPANS FOR RAFTERS AND CEILING JOINTS

Spans are based on Repetitive Member Values for Normal Duration of Loading. The allowable span is the clear distance between supports, or the horizontal projection of the rafter.

CEILING JOISTS (Drywall Ceiling)		Limited attic storage where development of future rooms is not possible Liveload 20 lb./sq. ft. Deadload 10 lb./sq. ft. Deflection—1/240th of span											No attic storage and roof slope not steeper than 3 in 12 Liveload 10 lb./sq. ft. Deadload 5 lb./sq. ft. Deflection—1/240th of span										
		Maximum Allowable Spans in Feet and Inches											*Maximum Allowable Spans in Feet and Inches*										
Size in	*Spacing in*	*Southern Pine*					*Douglas Fir-Larch*		*Hem-Fir*		*Spruce-Pine-Fir*		*Southern Pine*					*Douglas Fir-Larch*		*Hem-Fir*		*Spruce-Pine-Fir*	
Inches	*Inches*	*No. 1* KD	*No.* 2MG KD	*No.* 2MG	*No. 2* KD	*No. 3* KD	*No. 2*	*No. 3*	*No. 2*	*No. 3*	*No. 2*	*No. 3*	*No. 1* KD	*No.* 2MG KD	*No.* 2MG	*No. 2* KD	*No. 3* KD	*No. 2*	*No. 3*	*No. 2*	*No. 3*	*No. 2*	*No. 3*
2 × 4	12	10-5	10-0	9-10	9-8	8-2	10-0	7-11	9-5	7-0	8-10	6-8	13-2	12-8	12-5	12-2	11-8	12-8	11-3	11-10	9-11	11-7	9-5
	16	9-6	9-1	8-11	8-9	7-1	9-1	6-10	8-2	6-1	7-8	5-9	11-11	11-6	11-3	11-0	10-2	11-6	9-9	10-9	8-7	10-6	8-2
	24	8-3	7-10	7-6	7-1	5-9	7-6	5-7	6-8	5-0	6-3	4-8	10-5	10-0	9-10	9-8	8-3	10-0	7-11	9-5	7-0	8-10	6-8
2 × 6	12	16-4	15-9	15-6	14-9	12-5	15-7	11-11	13-11	10-8	13-0	9-10	20-8	19-11	19-6	19-1	17-7	19-11	16-11	18-8	15-1	18-2	13-11
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	24	13-0	12-0	11-0	10-5	8-9	11-0	8-5	9-10	7-6	9-2	6-11	16-4	15-9	15-6	14-9	12-5	15-7	11-11	13-11	10-8	13-0	9-10
2 × 8	12	21-7	20-10	20-5	19-6	16-4	20-7	15-9	18-4	14-0	17-1	12-11	27-2	26-2	25-8	25-2	23-3	26-2	22-3	24-7	19-10	24-0	18-4
	16	19-7	18-4	17-10	16-10	14-2	17-10	13-8	15-10	12-2	14-10	11-3	24-8	23-10	23-4	22-10	20-1	23-10	19-4	22-4	17-2	20-11	15-10
	24	17-2	15-10	14-6	13-9	11-8	14-7	11-2	12-11	9-11	12-1	9-2	21-7	20-10	20-5	19-6	16-4	20-7	15-9	18-4	14-0	17-1	12-11
2 × 10	12	27-6	26-6	26-0	24-10	20-11	26-3	20-1	23-5	17-11	21-10	16-6	34-8	33-5	32-9	32-1	29-7	33-5	28-5	31-4	25-4	30-7	23-5
	16	25-0	23-6	22-9	21-7	18-1	26-3	17-5	20-3	15-6	18-11	14-4	31-6	30-5	29-9	29-2	25-7	30-5	24-7	28-6	21-11	26-8	20-3
	16	25-0	23-6	22-9	21-7	18-1	22-9	14-3	16-6	12-8	15-5	11-8	27-6	26-6	26-0	24-10	21-0	26-3	20-1	23-5	17-11	21-10	16-6
	24	21-10	10-2	18-6	17-7	14-11	18-7																

RAFTERS		HIGH SLOPE SLOPE OVER 8 in 12 (Light Roof Covering)											LOW SLOPE SLOPE 3 in 12 or LESS (No Finished Ceiling)										
		Liveload 20 lb./sq. ft.											Liveload 20 lb./sq. ft.										
		Deadload 7 lb./sq. ft.				Deflection—1/18th of span							Deadload 10 lb./sq. ft.				Deflection—1/240th of span						
2 × 4	12	11-5	11-10	10-10	10-7	9-3	11-1	9-4	10-4	8-4	10-0	7-10	16-5	15-9	15-5	15-1	13-10	15-9	13-4	14-9	11-11	14-5	11-0
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2 × 6	12	18-0	17-3	17-0	16-8	14-8	17-4	14-1	16-3	12-6	15-3	11-7	21-7	20-9	20-4	19-11	18-4	20-10	17-7	19-6	15-8	19-1	14-6
	16	16-4	15-9	15-5	15-1	12-8	15-9	12-2	14-2	10-10	13-3	10-0	19-7	18-11	18-6	18-2	15-10	18-11	15-3	17-9	13-7	16-6	12-7
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2 × 8	12	23-9	22-10	22-5	22-0	19-4	22-11	18-7	21-5	16-6	20-1	15-3	27-7	26-6	26-0	25-5	23-4	26-6	22-5	24-10	20-0	24-4	18-6
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2 × 10	12	30-3	30-1	28-7	28-1	24-7	29-2	23-8	27-5	21-1	25-8	19-6	33-6	32-3	31-7	30-11	28-5	32-3	27-4	30-3	24-4	29-6	22-6
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NOTE: The Grademark that is required on each piece of material provides the species of lumber and its grade. For Species and Grades other than those covered by the above table, refer to the "Span Tables for Joists and Rafters" as published by the National Forest Products Association.

TABLE 3-4

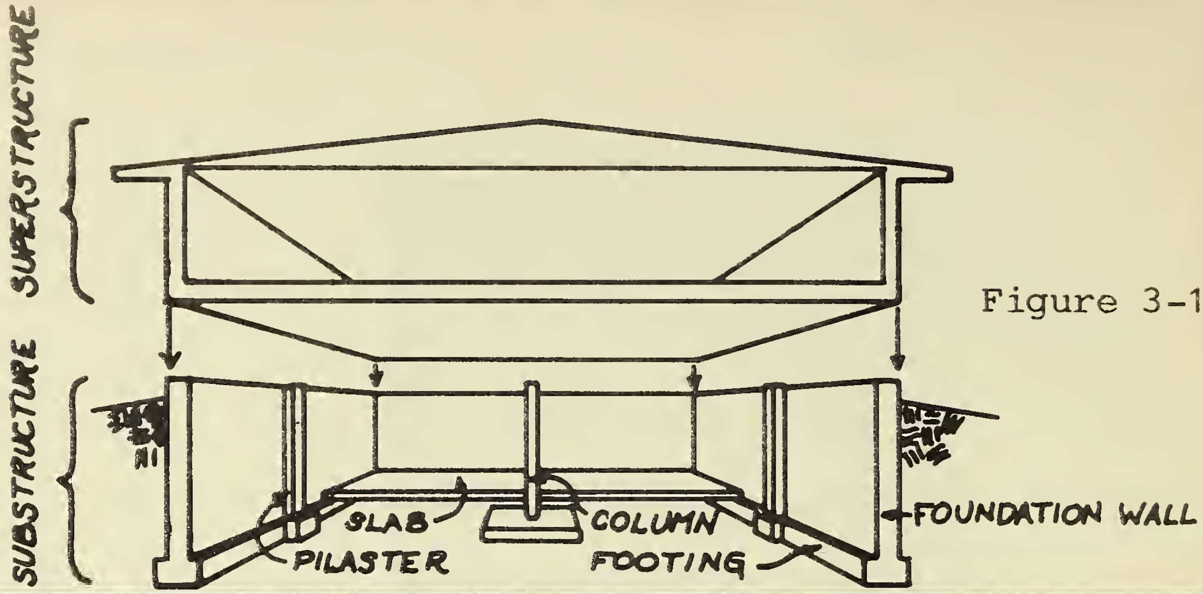


Figure 3-1

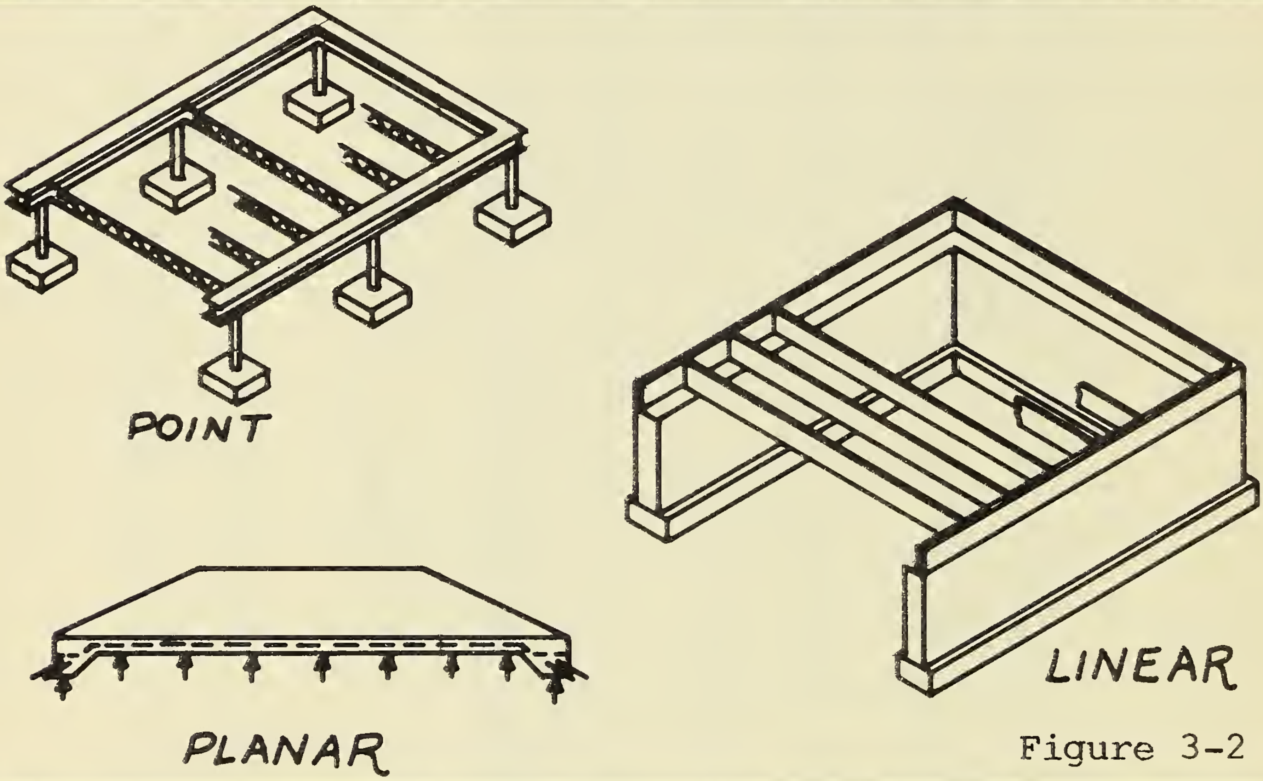


Figure 3-2

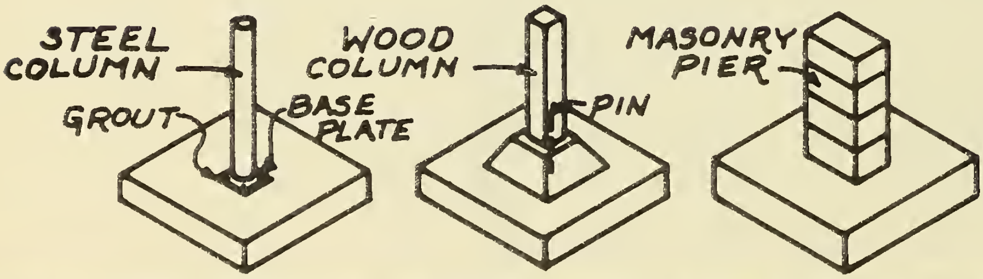


Figure 3-3

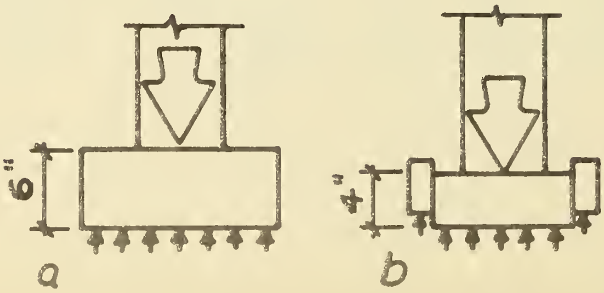


Figure 3-4

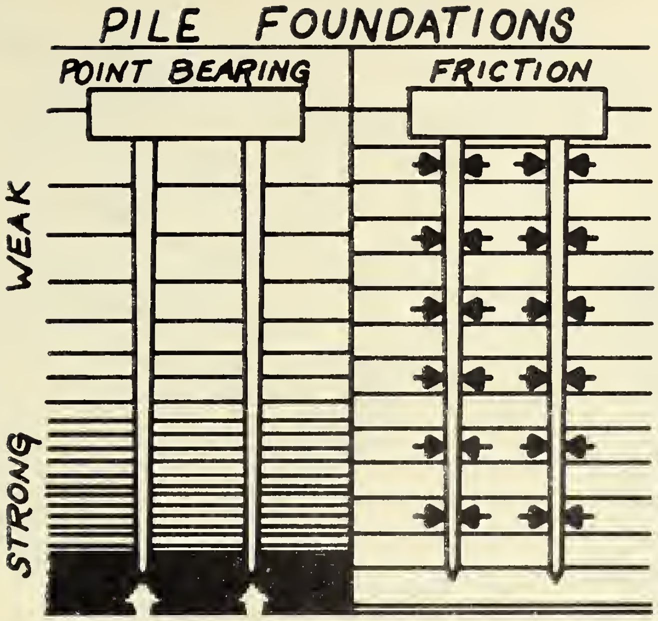


Figure 3-5

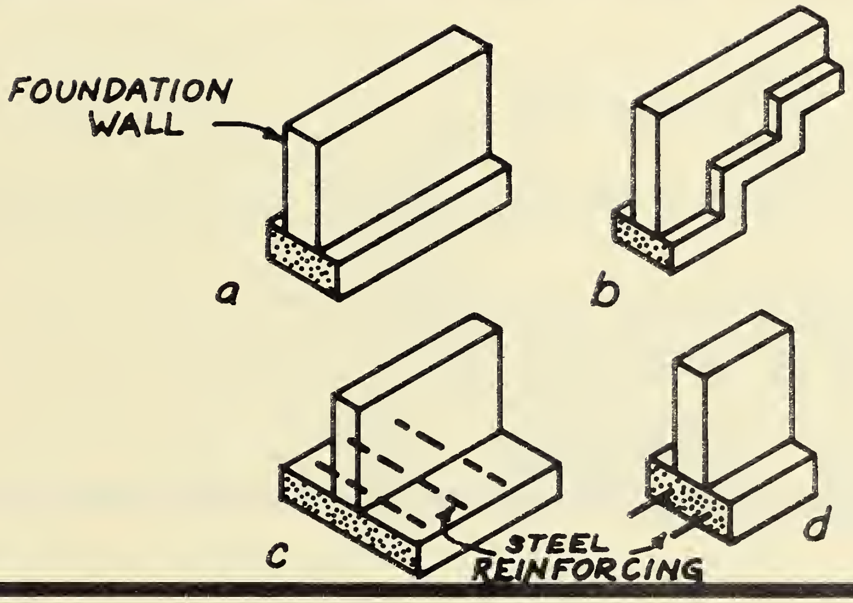


Figure 3-6

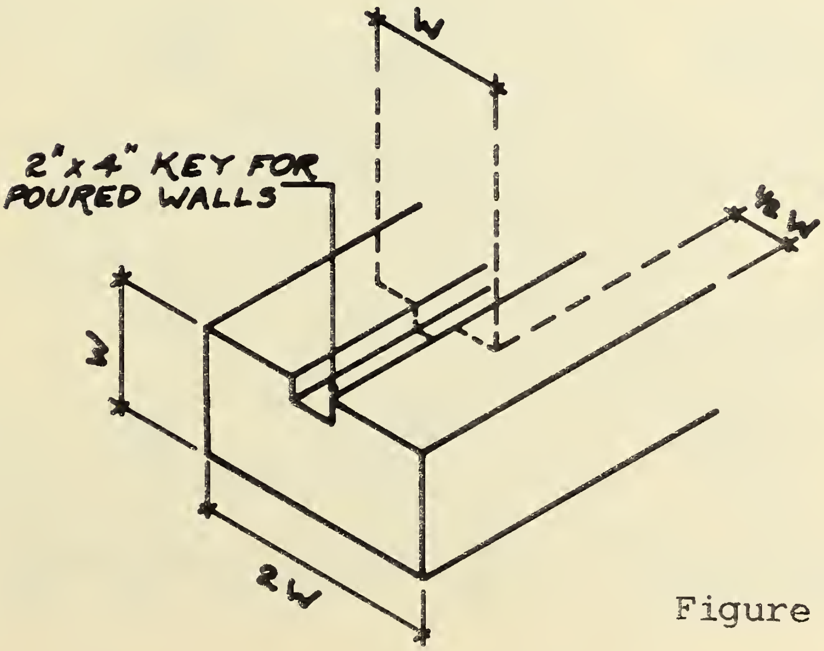
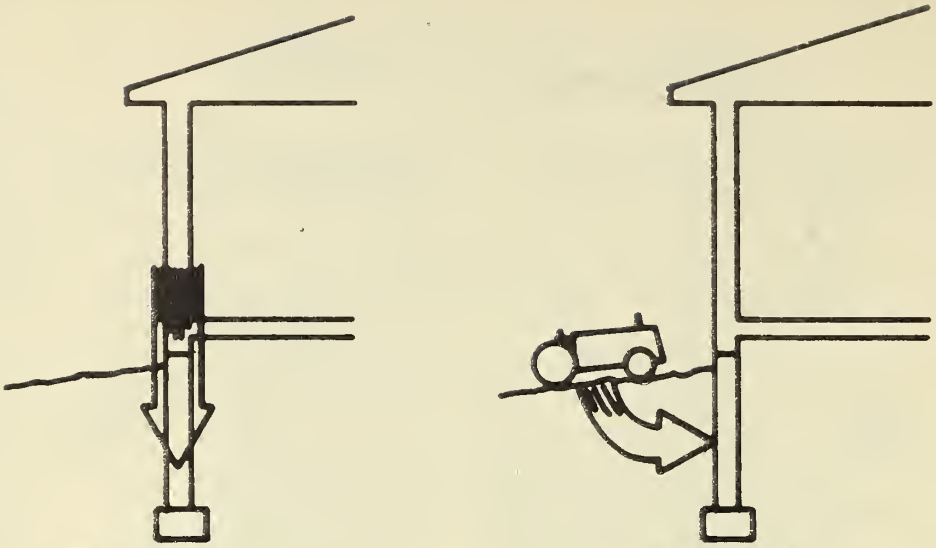


Figure 3-7



VERTICAL LOAD

LATERAL LOAD

Figure 3-8

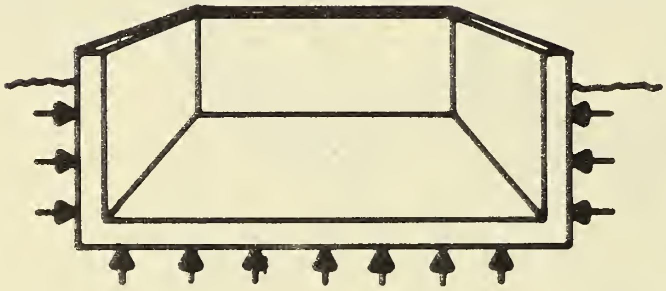
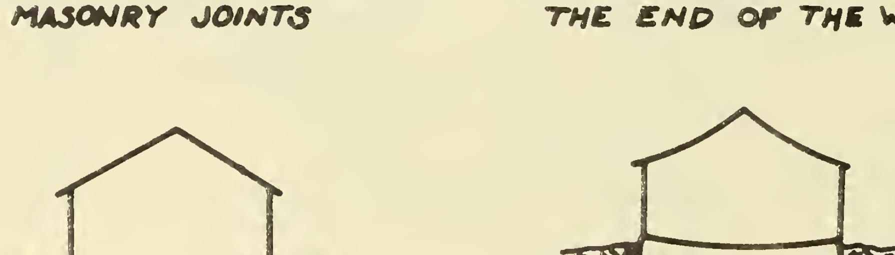


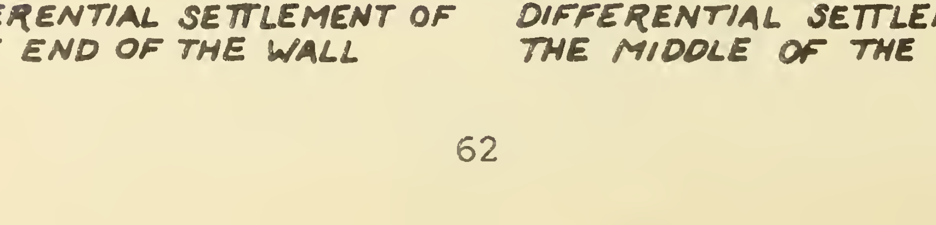
Figure 3-9

Figure 3-10



CRACKS IN FOUNDATION WALL ALONG MASONRY JOINTS

DIFFERENTIAL SETTLEMENT OF THE END OF THE WALL



DIFFERENTIAL SETTLEMENT OF THE END OF THE WALL

DIFFERENTIAL SETTLEMENT OF THE MIDDLE OF THE WALL

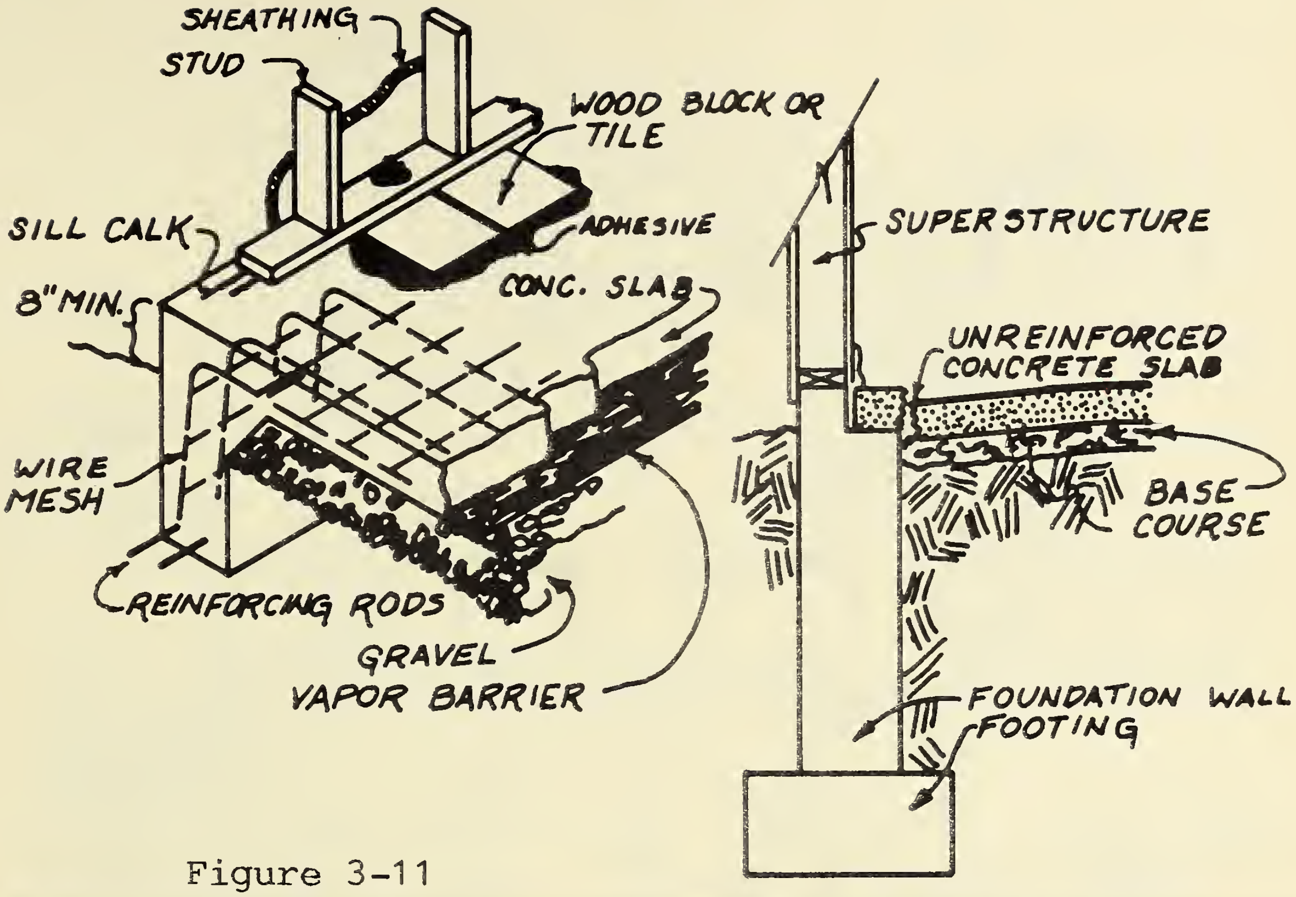


Figure 3-11

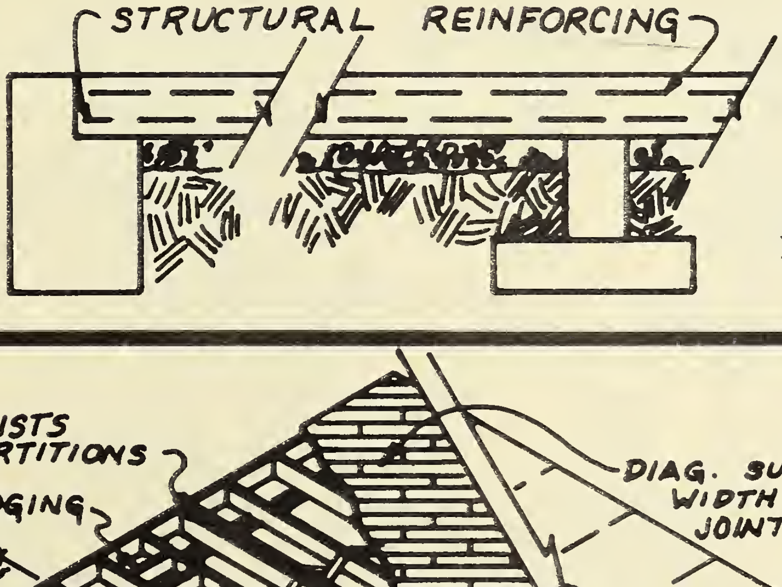


Figure 3-12

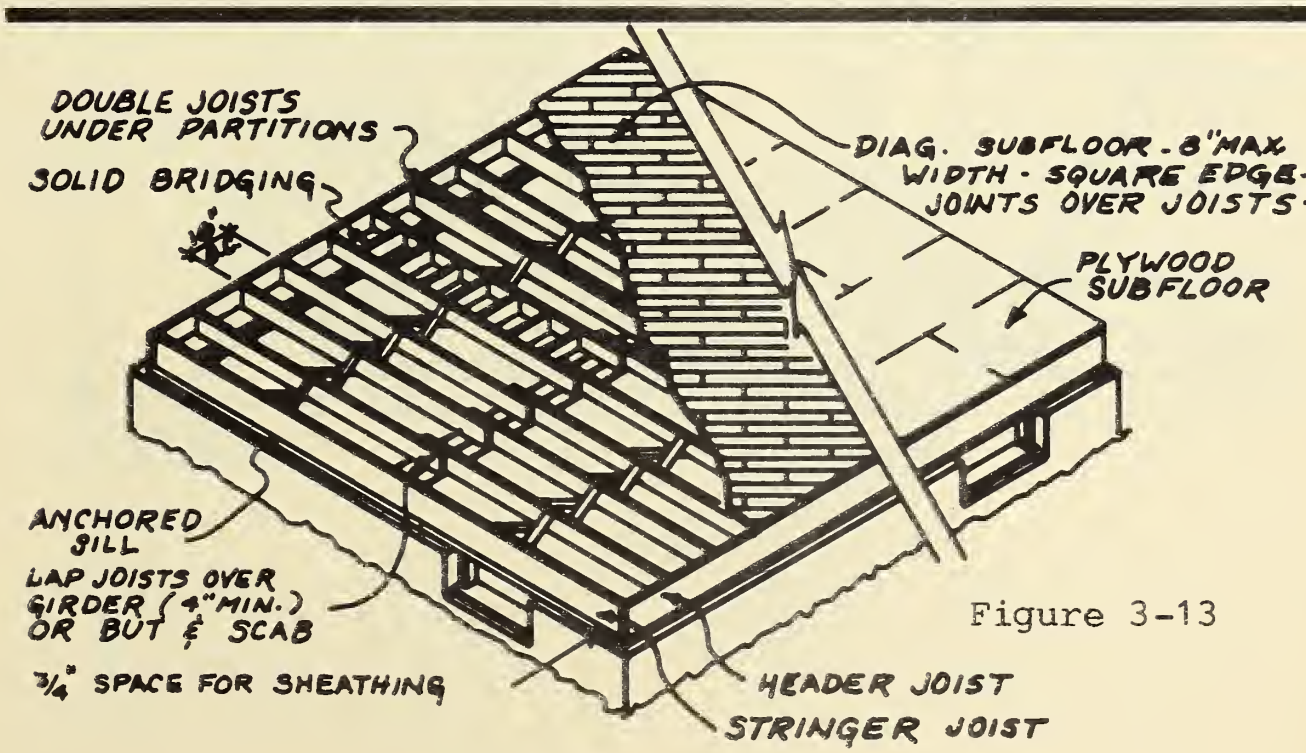

DOUBLE JOISTS UNDER PARTITIONS
SOLID BRIDGING
DIAG. SUBFLOOR - 8" MAX WIDTH - SQUARE EDGE - JOINTS OVER JOISTS -
PLYWOOD SUBFLOOR
ANCHORED SILL
LAP JOISTS OVER GIRDER (4" MIN.) OR BUT & SCAB
¾" SPACE FOR SHEATHING
HEADER JOIST
STRINGER JOIST

Figure 3-13

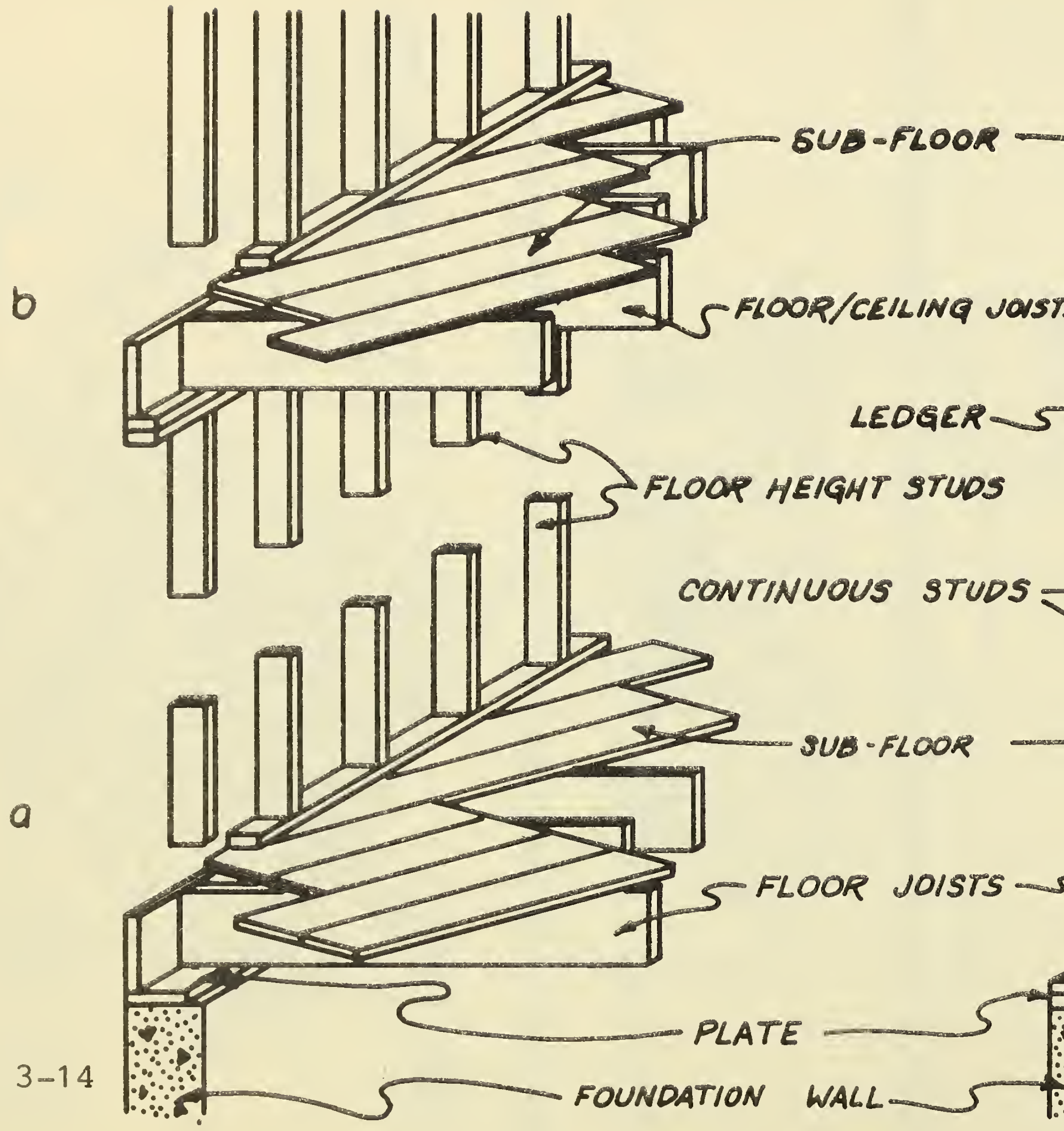


Figure 3-14

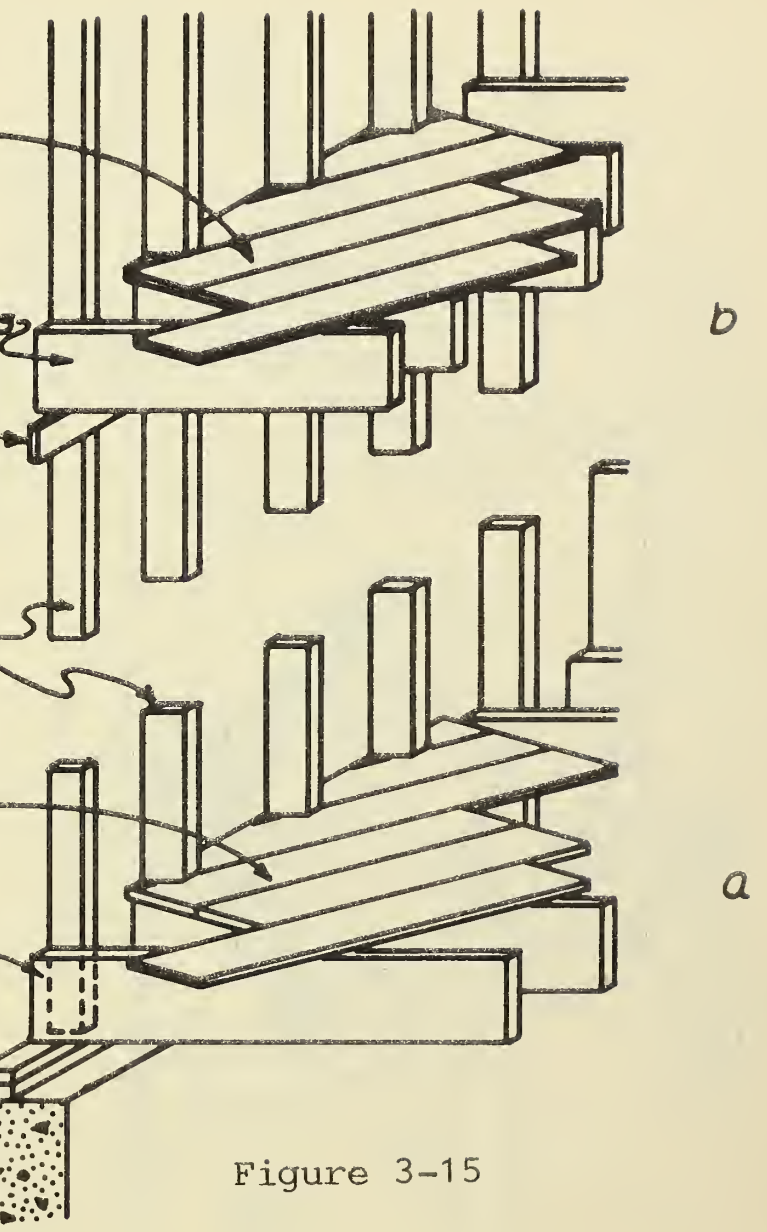


Figure 3-15

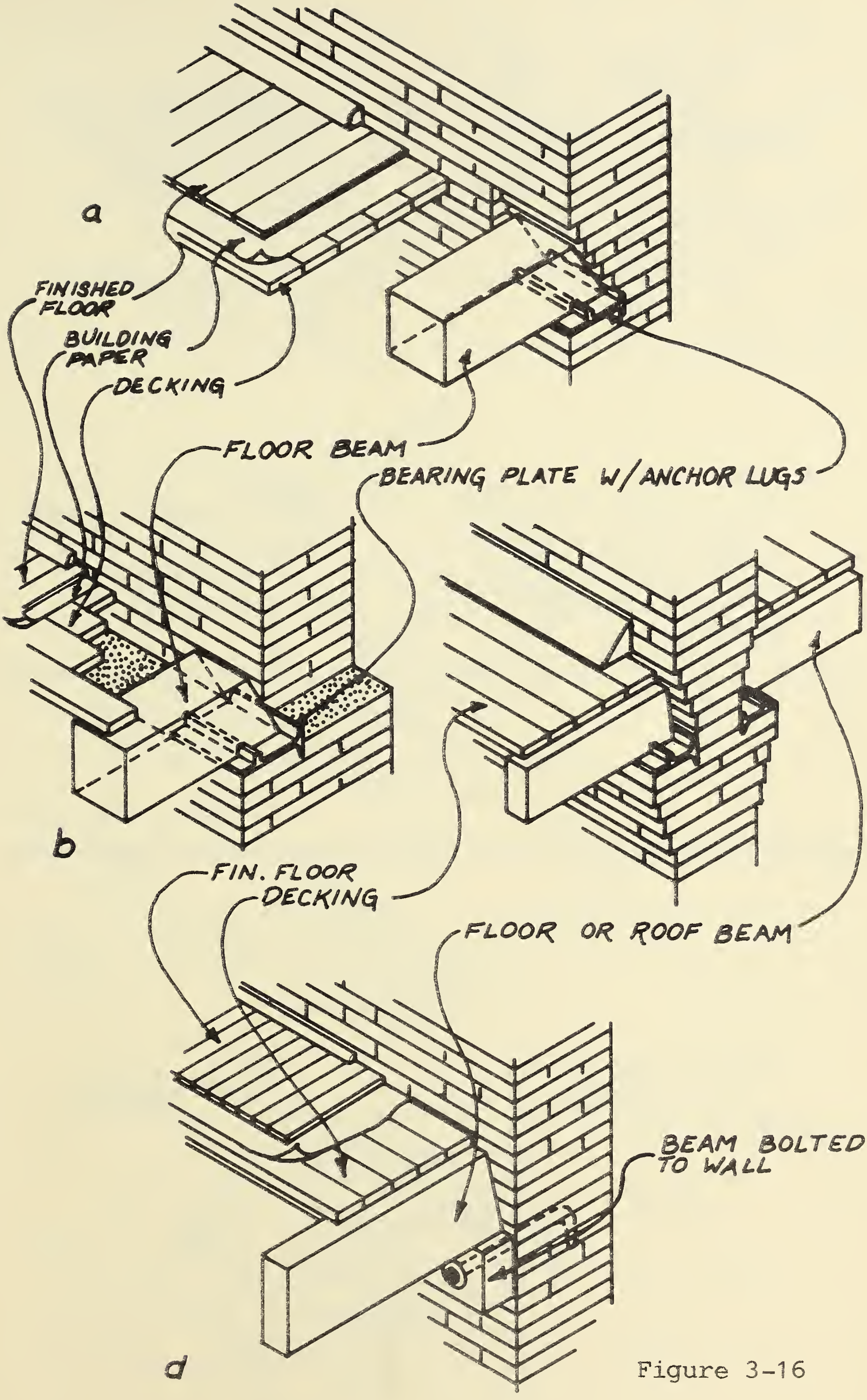

a
FINISHED FLOOR
BUILDING PAPER
DECKING
FLOOR BEAM
BEARING PLATE W/ANCHOR LUGS
b
c
FIN. FLOOR
DECKING
FLOOR OR ROOF BEAM
BEAM BOLTED TO WALL
d

Figure 3-16

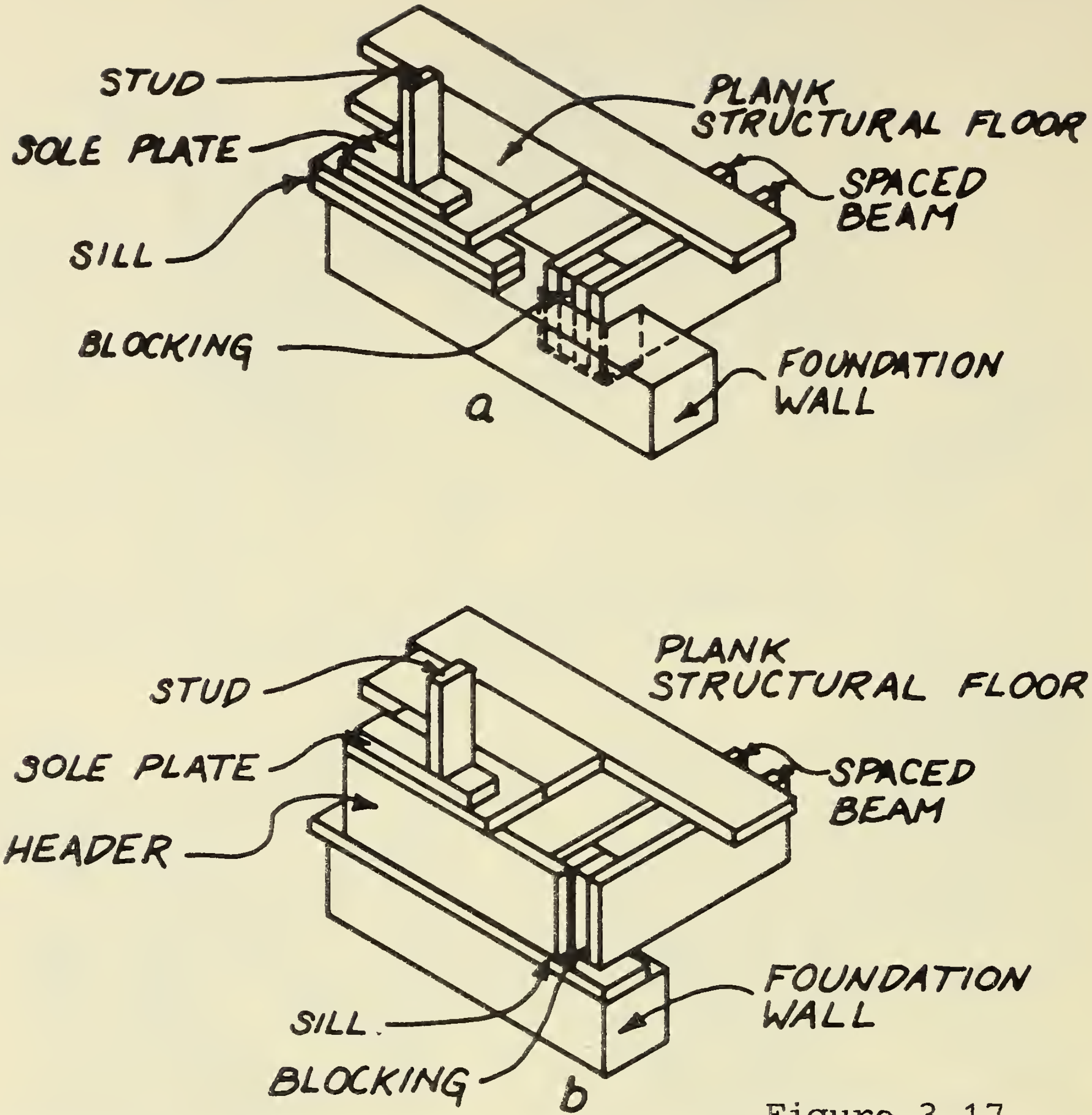


Figure 3-17

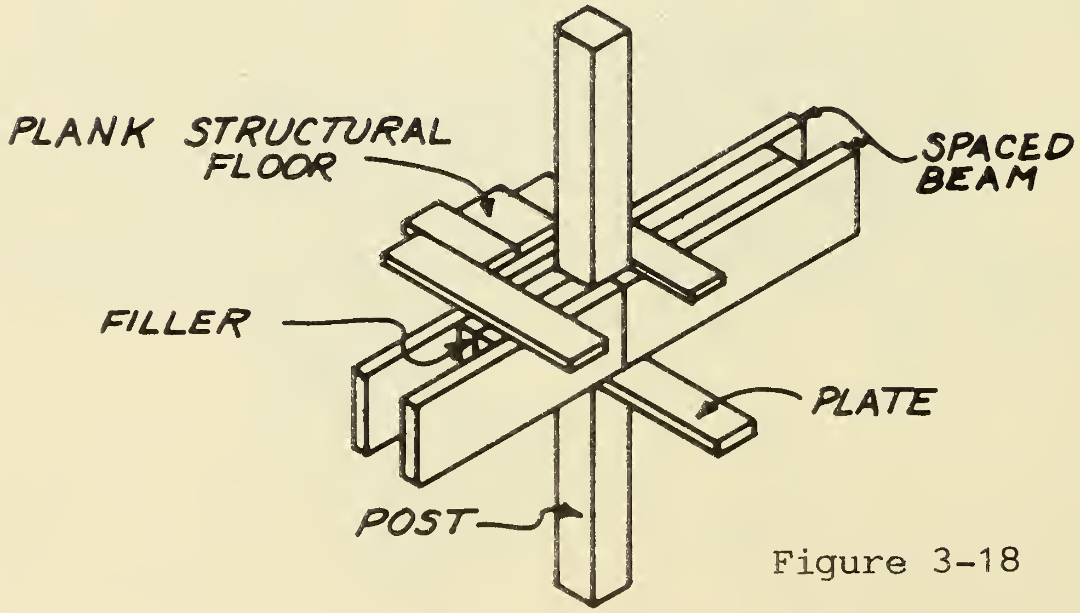


Figure 3-18

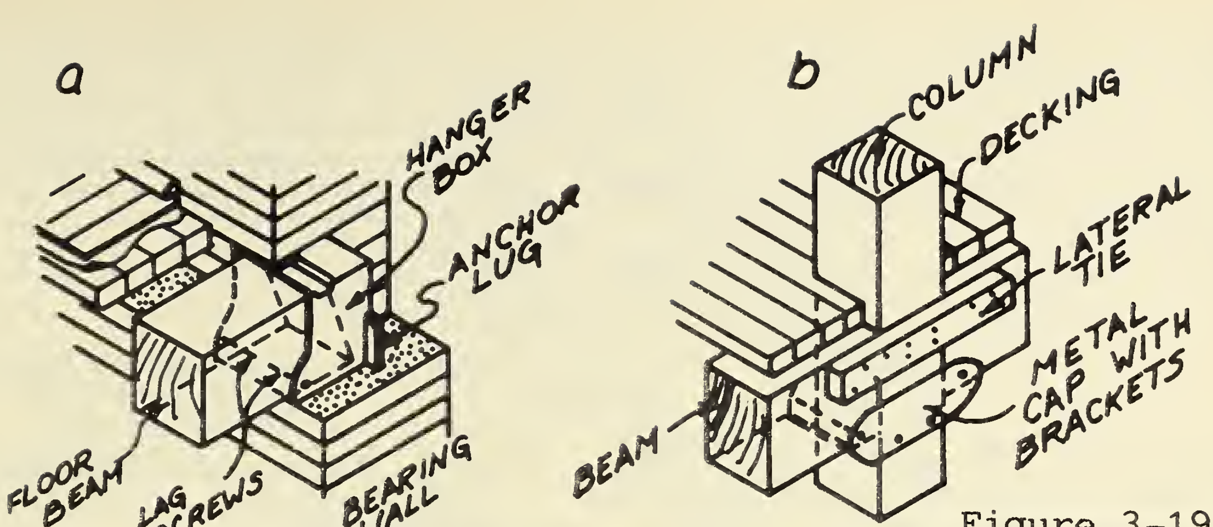


Figure 3-19

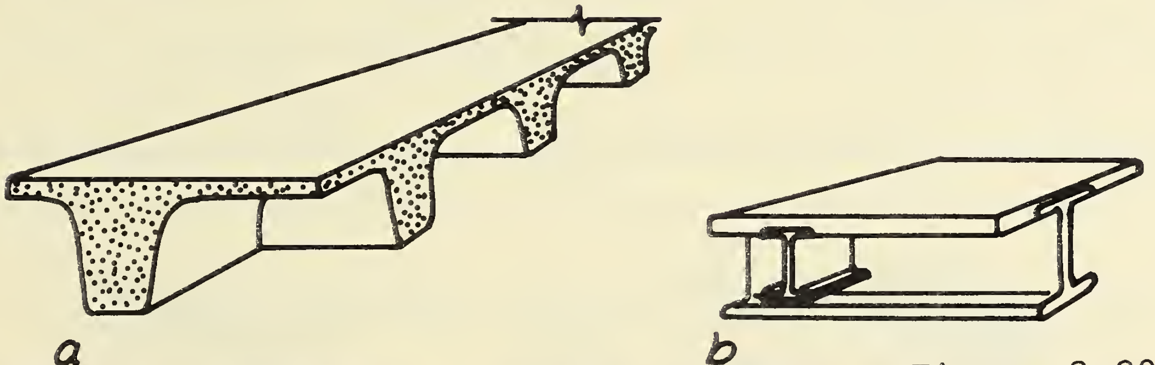


Figure 3-20

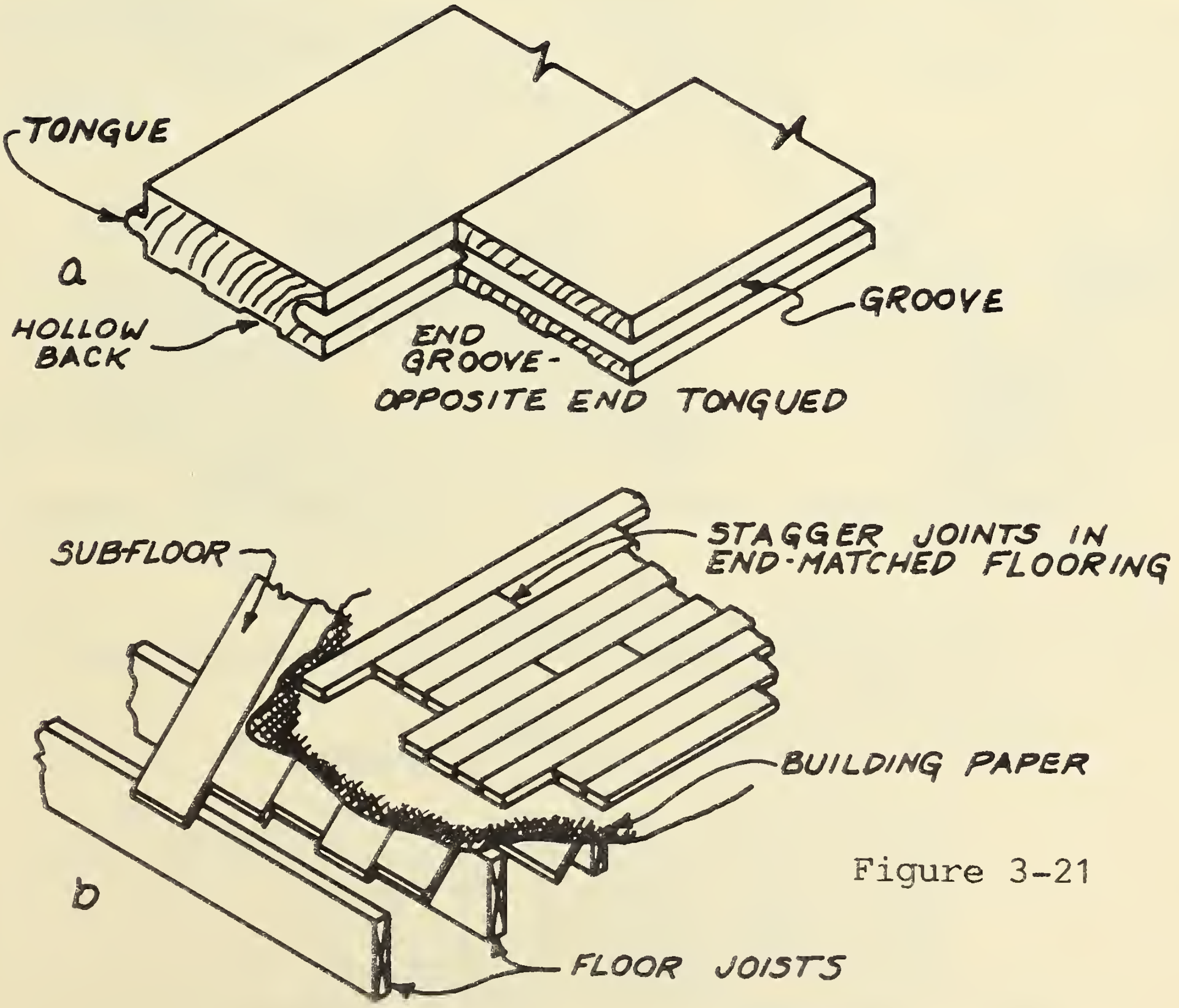


Figure 3-21

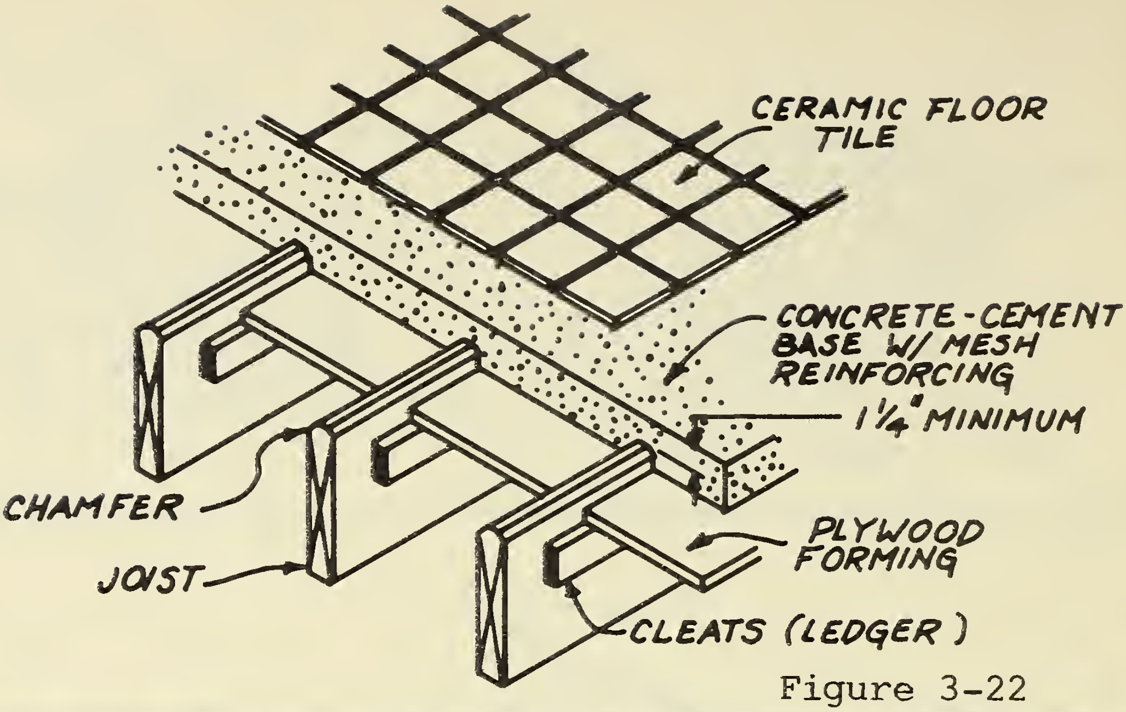
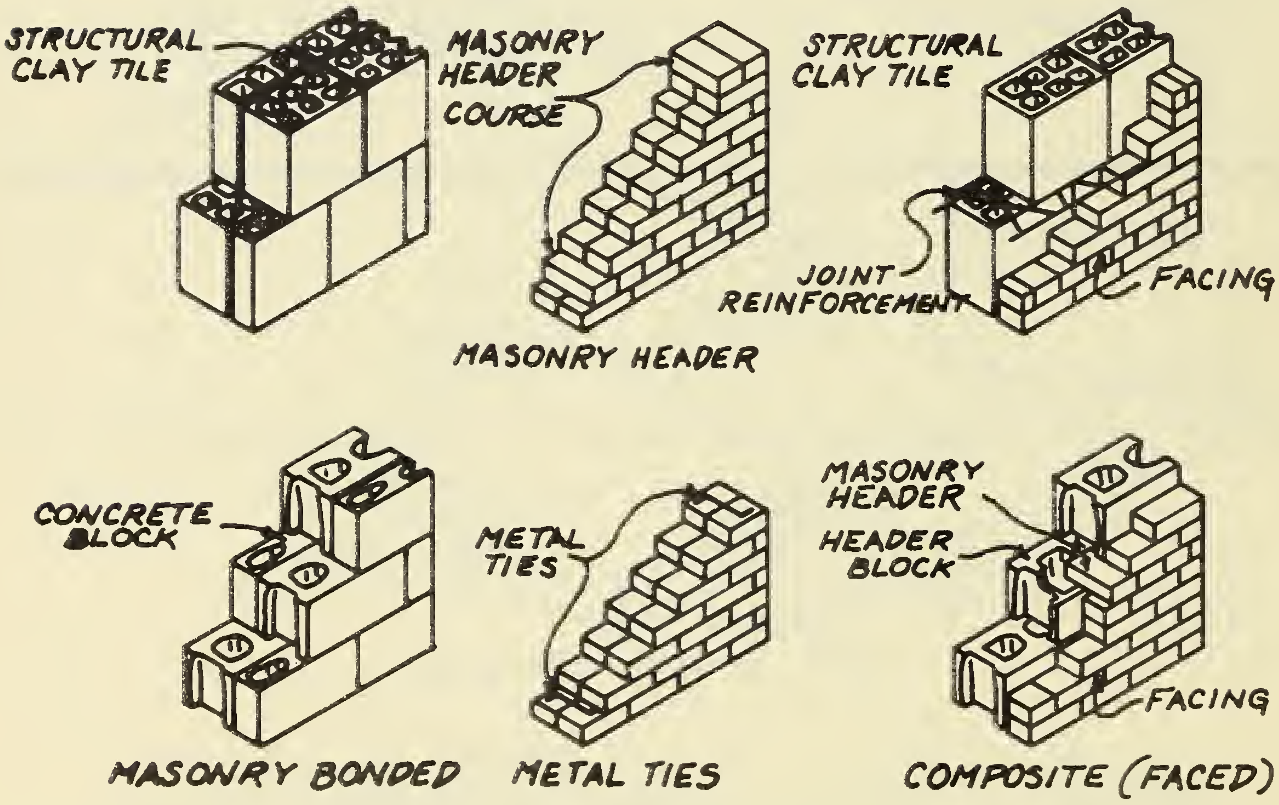


Figure 3-22



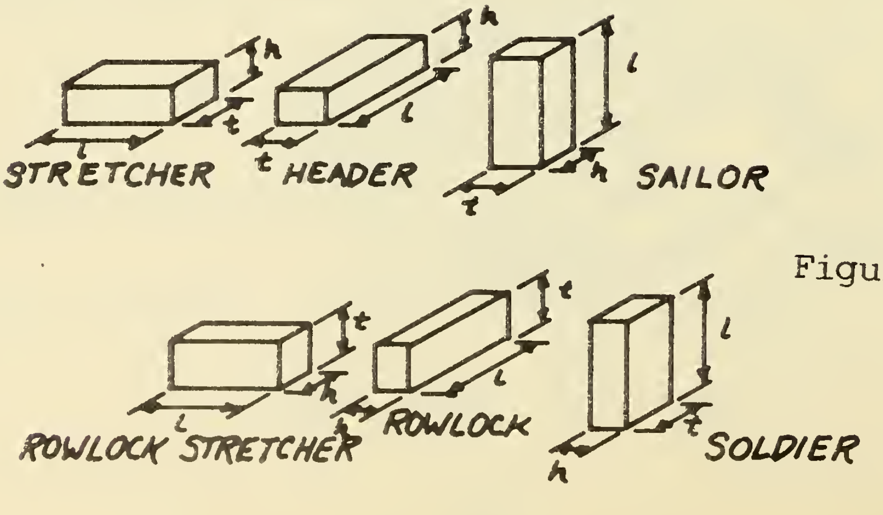
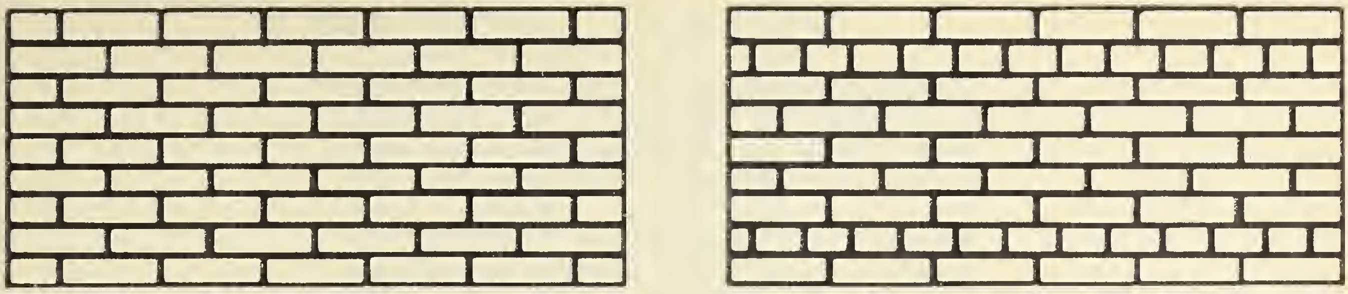
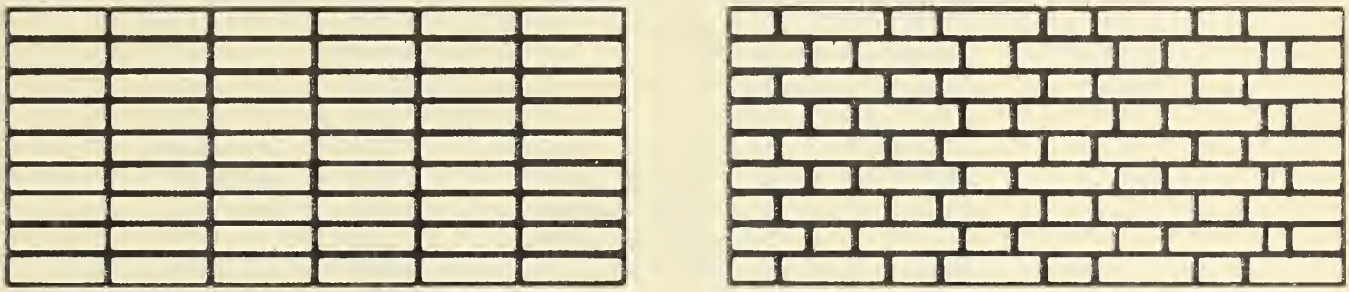


Figure 3-23



RUNNING BOND

6th COURSE HEADERS
COMMON BOND



STACK BOND

FLEMISH BOND

Figure 3-24

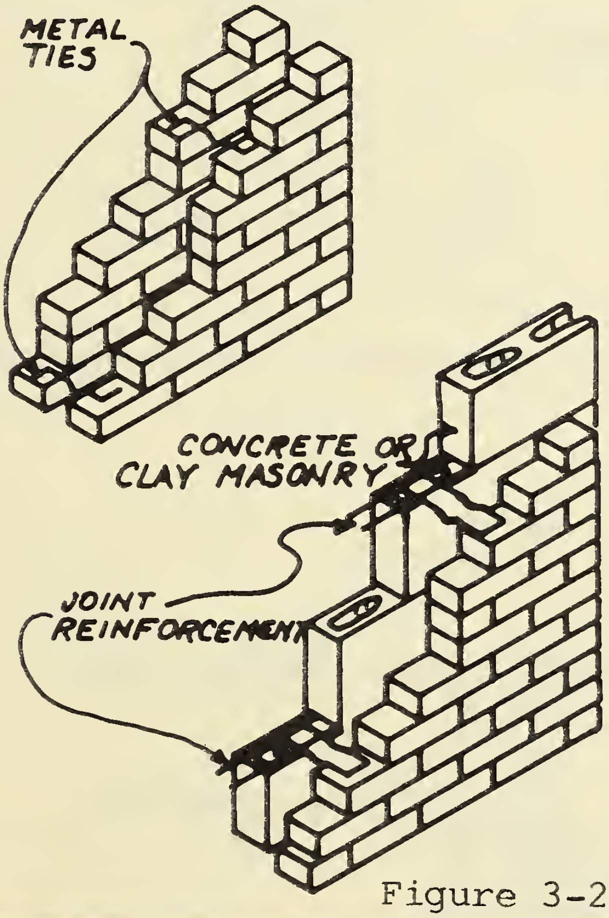
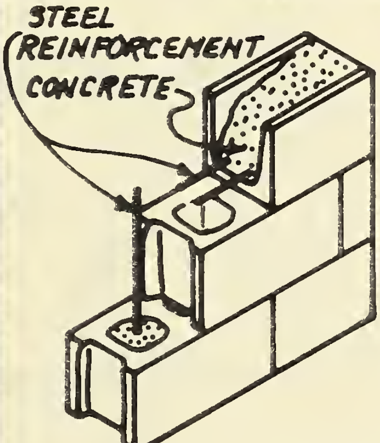
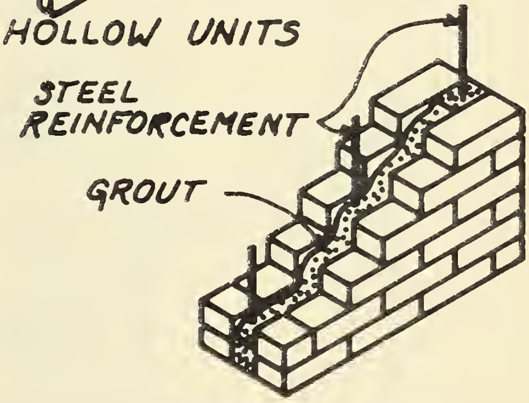


Figure 3-25



HOLLOW UNITS



SOLID UNITS

Figure 3-26

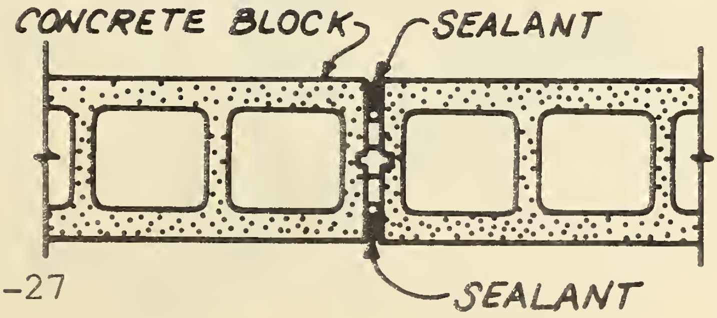


Figure 3-27

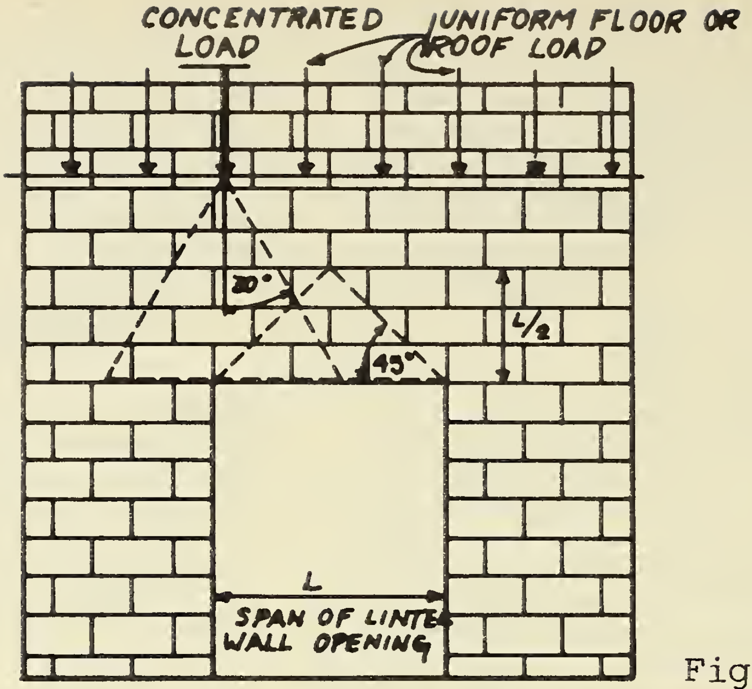


Figure 3-28

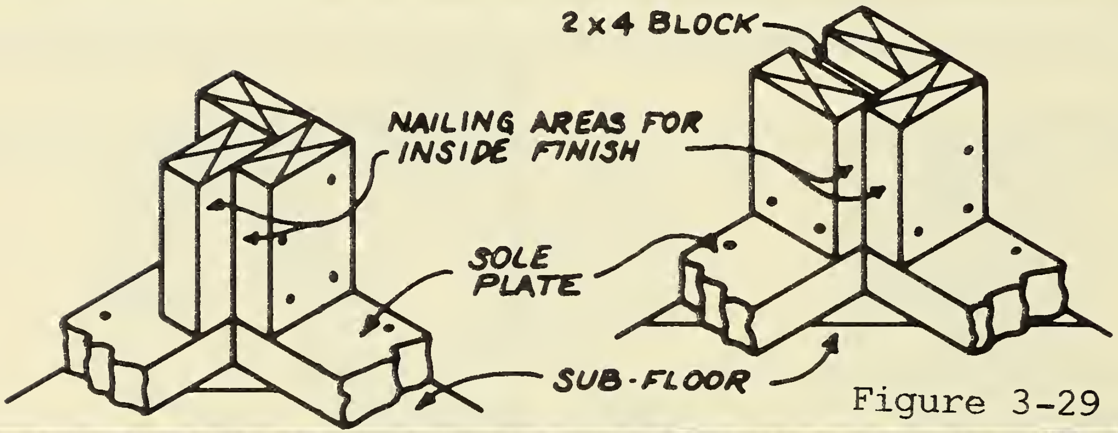


Figure 3-29

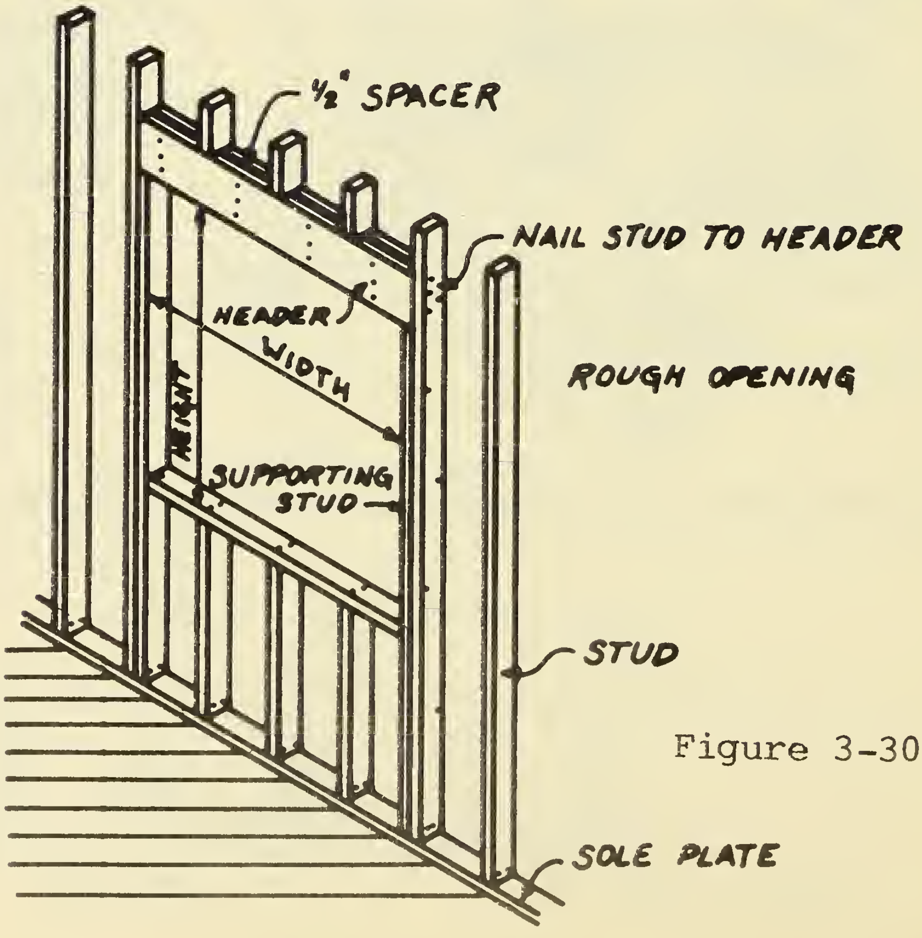
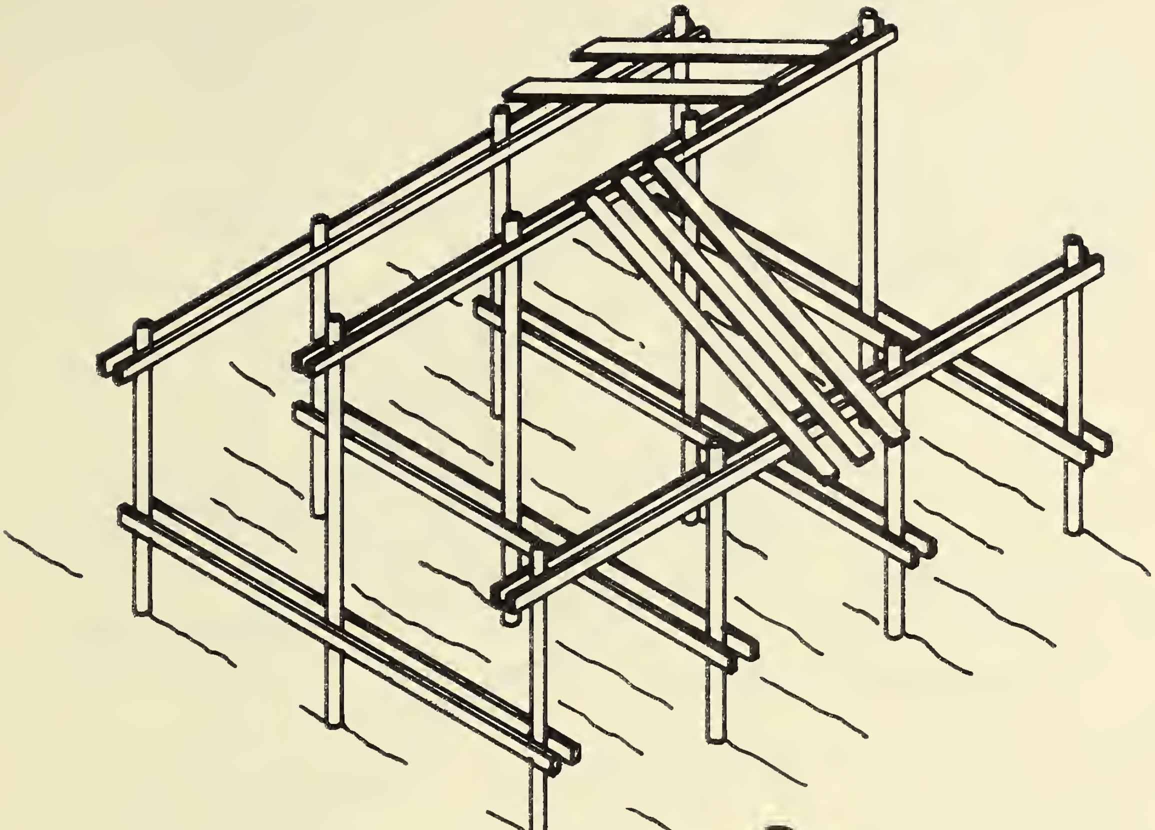


Figure 3-30



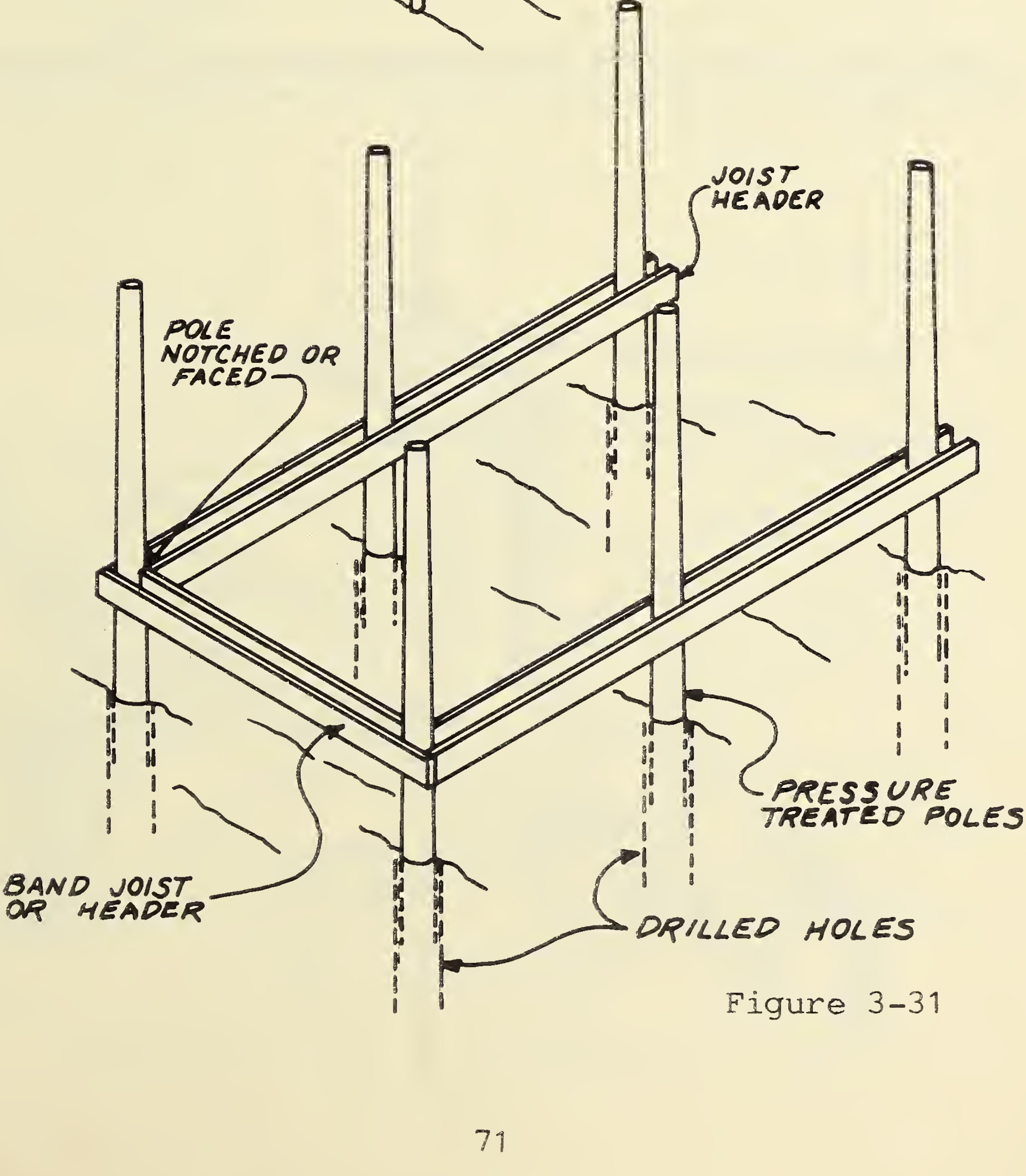
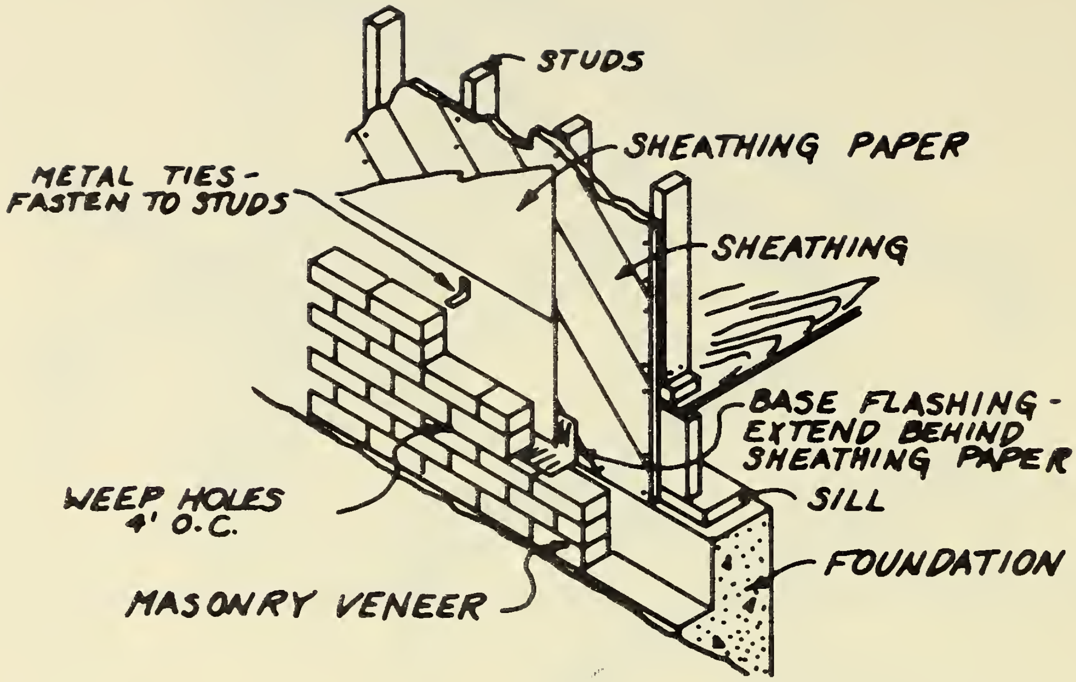

JOIST HEADER
POLE NOTCHED OR FACED
PRESSURE TREATED POLES
BAND JOIST OR HEADER
DRILLED HOLES

Figure 3-31



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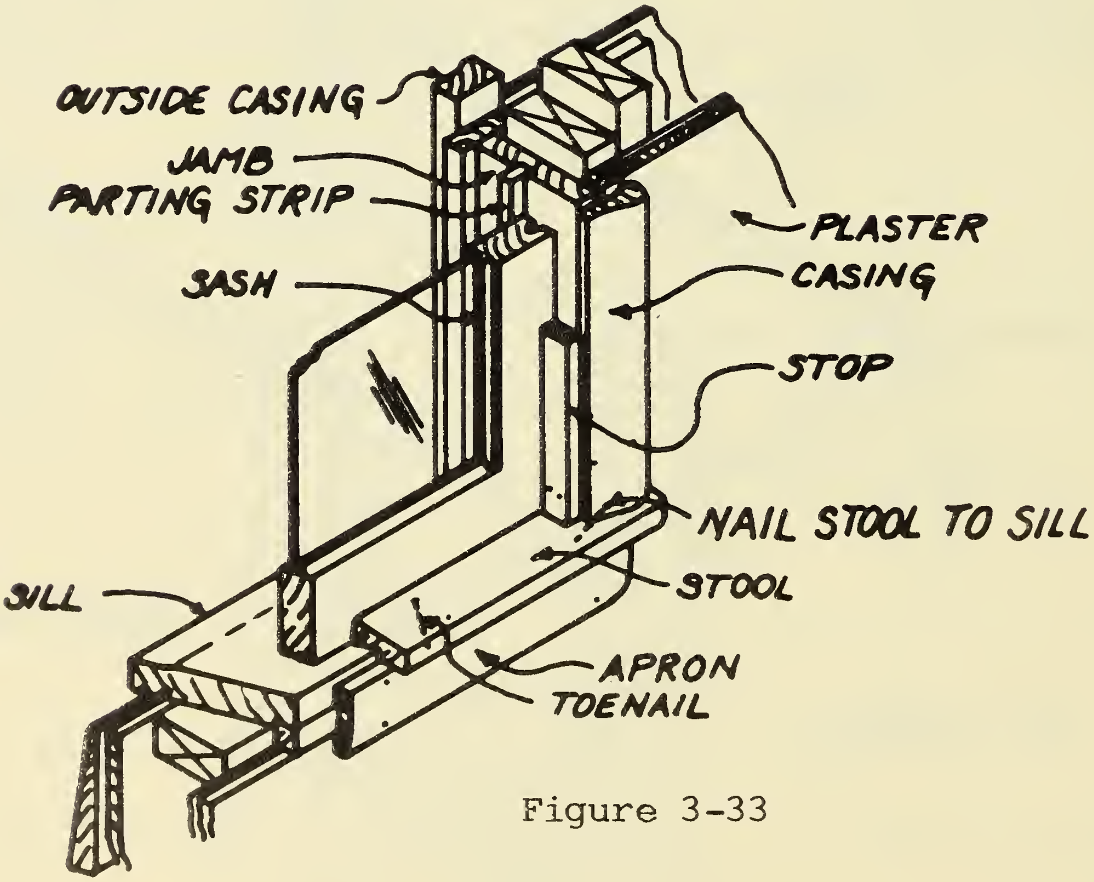

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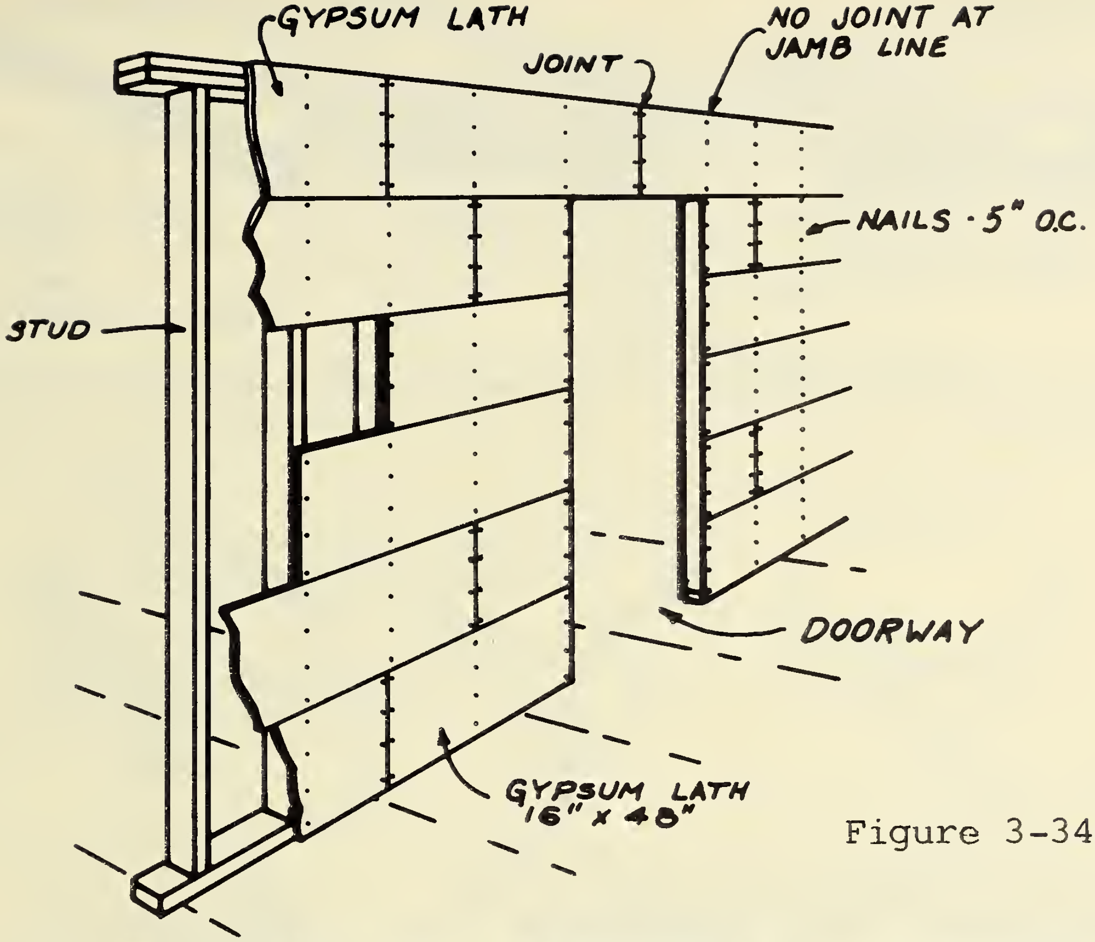
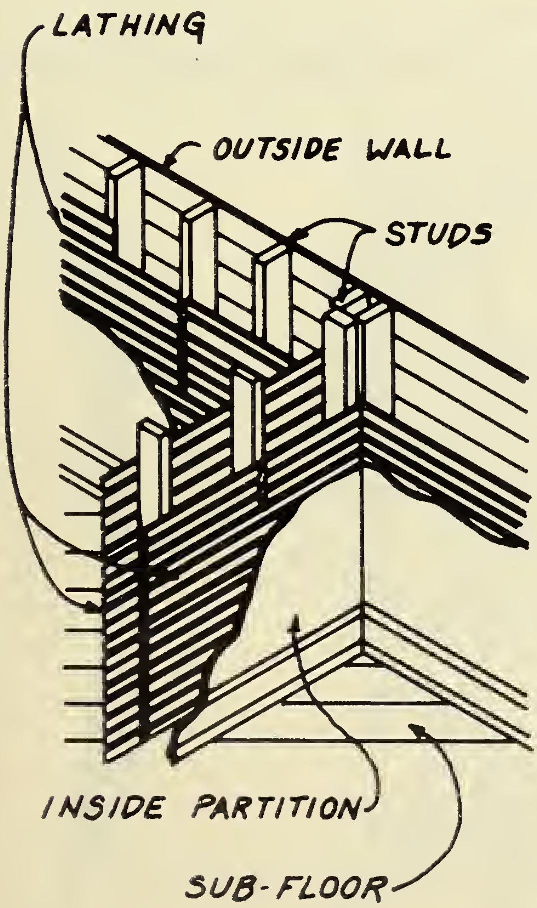


Figure 3-34

Figure 3-35



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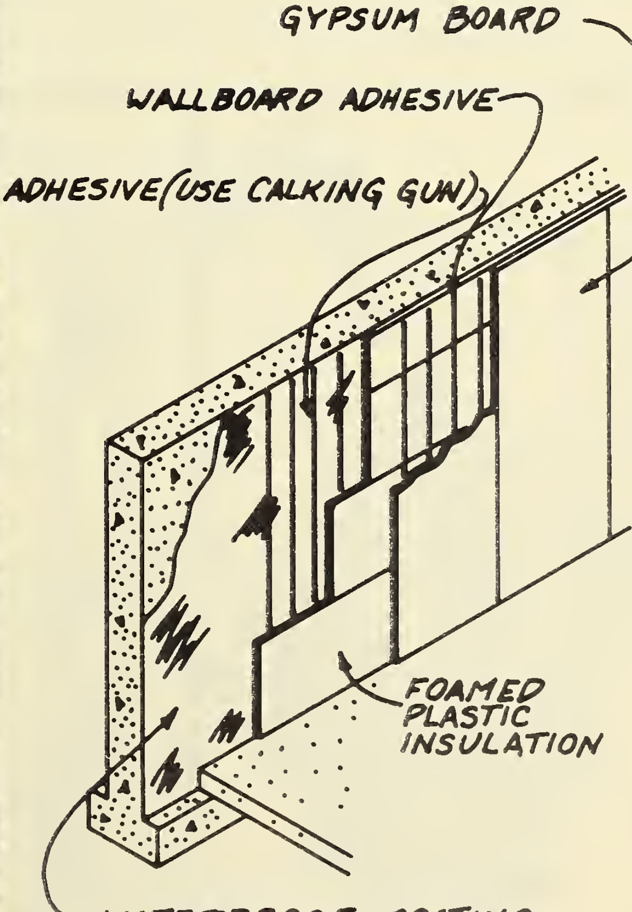

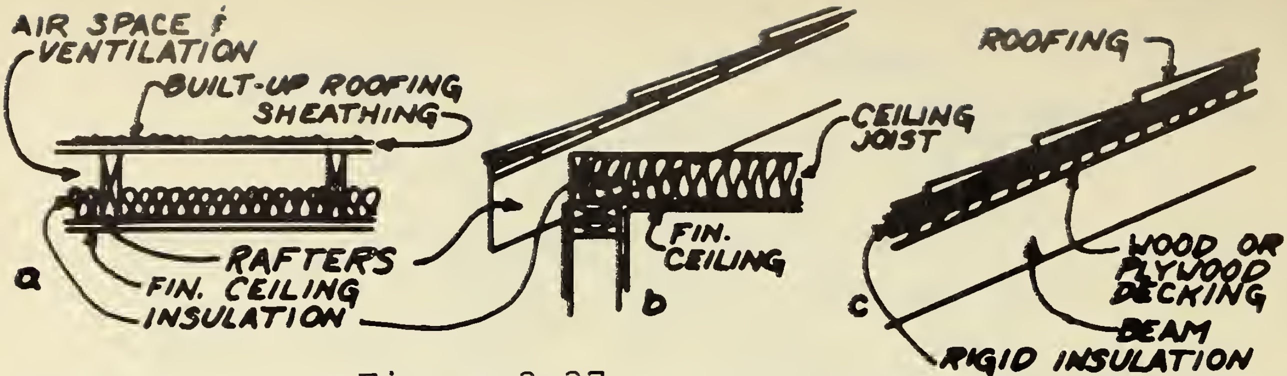

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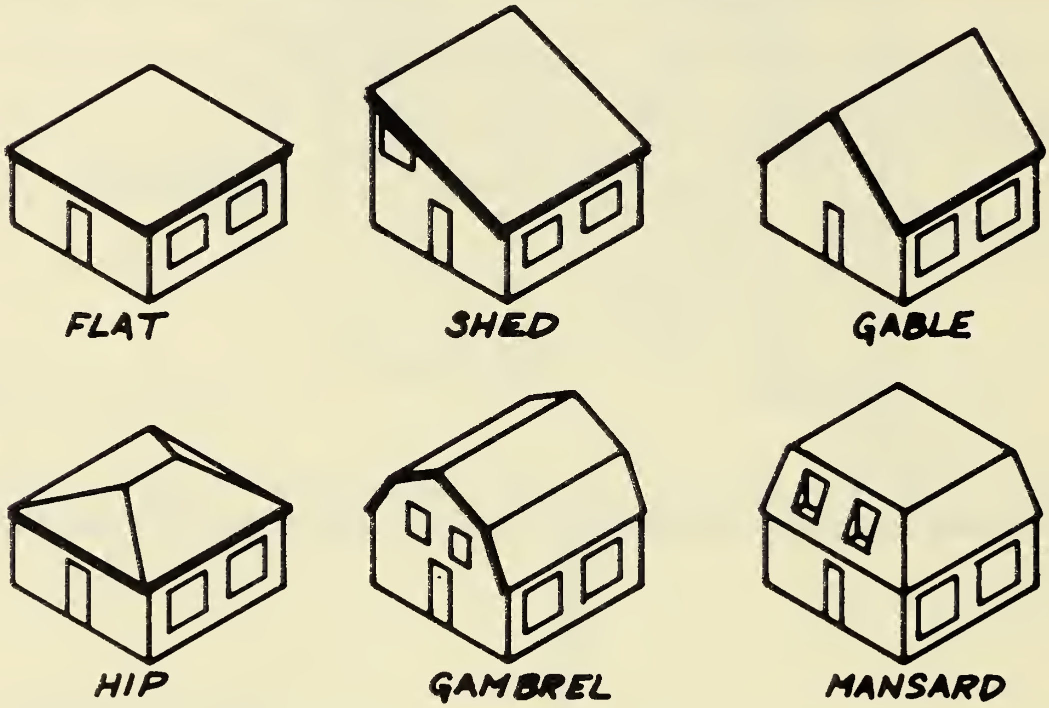

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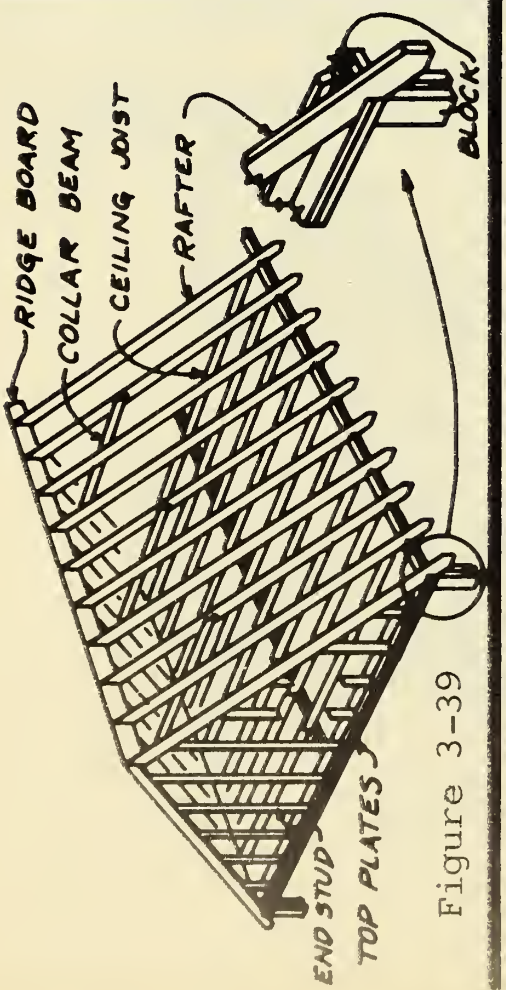

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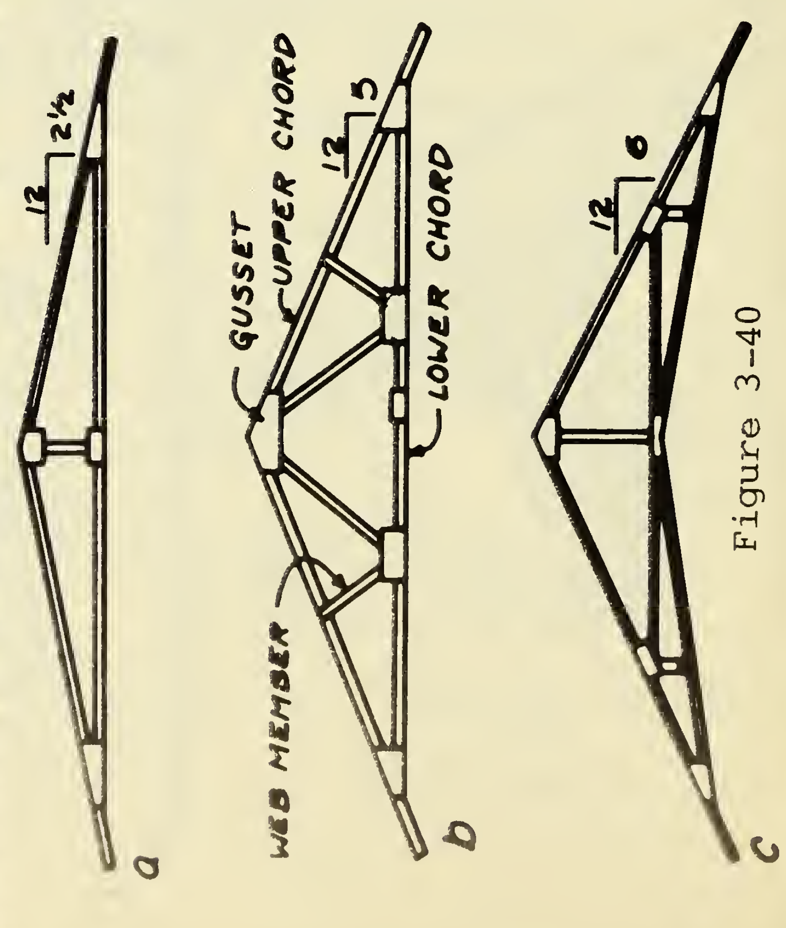

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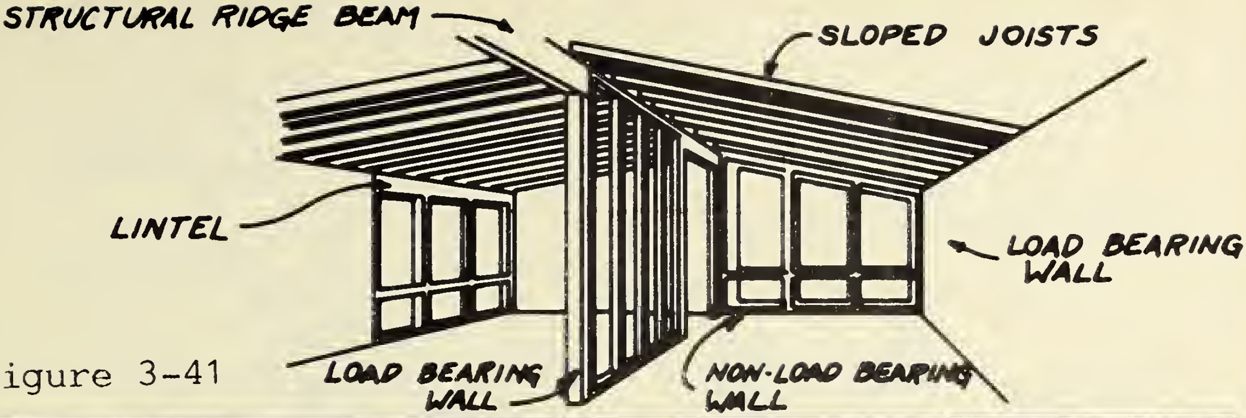

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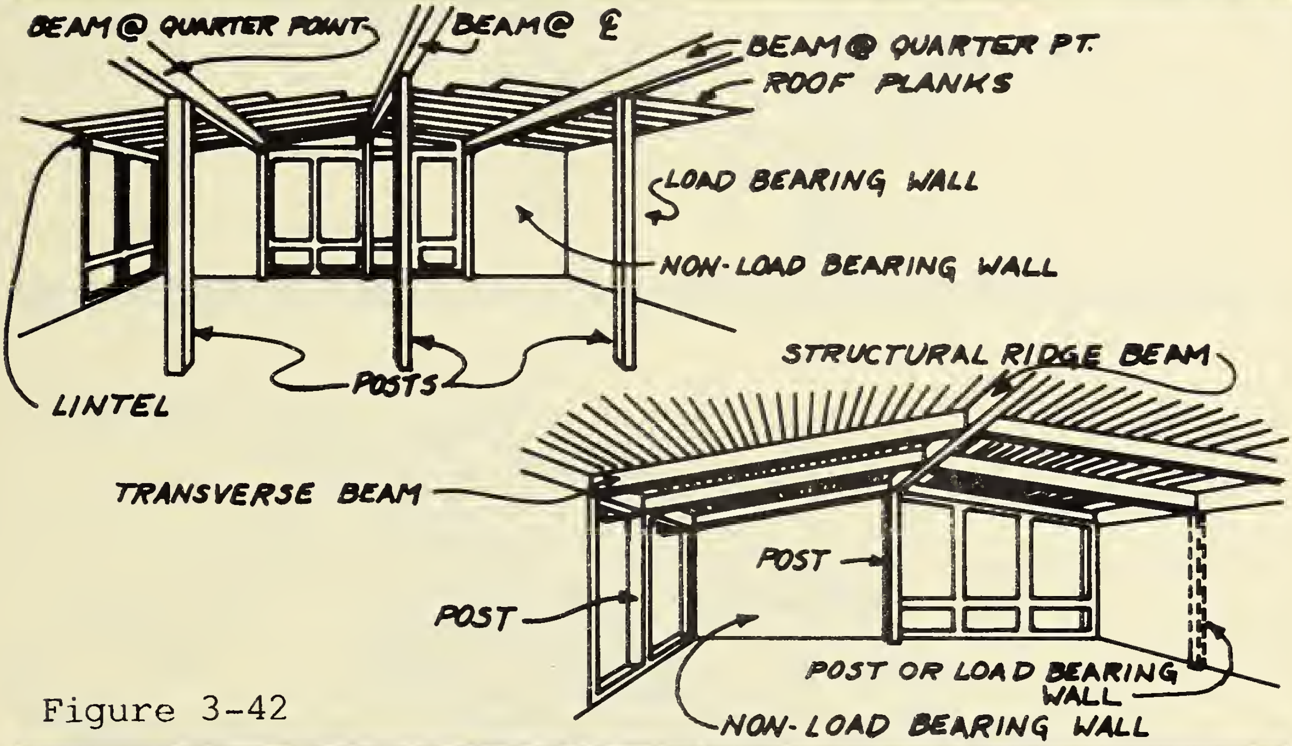

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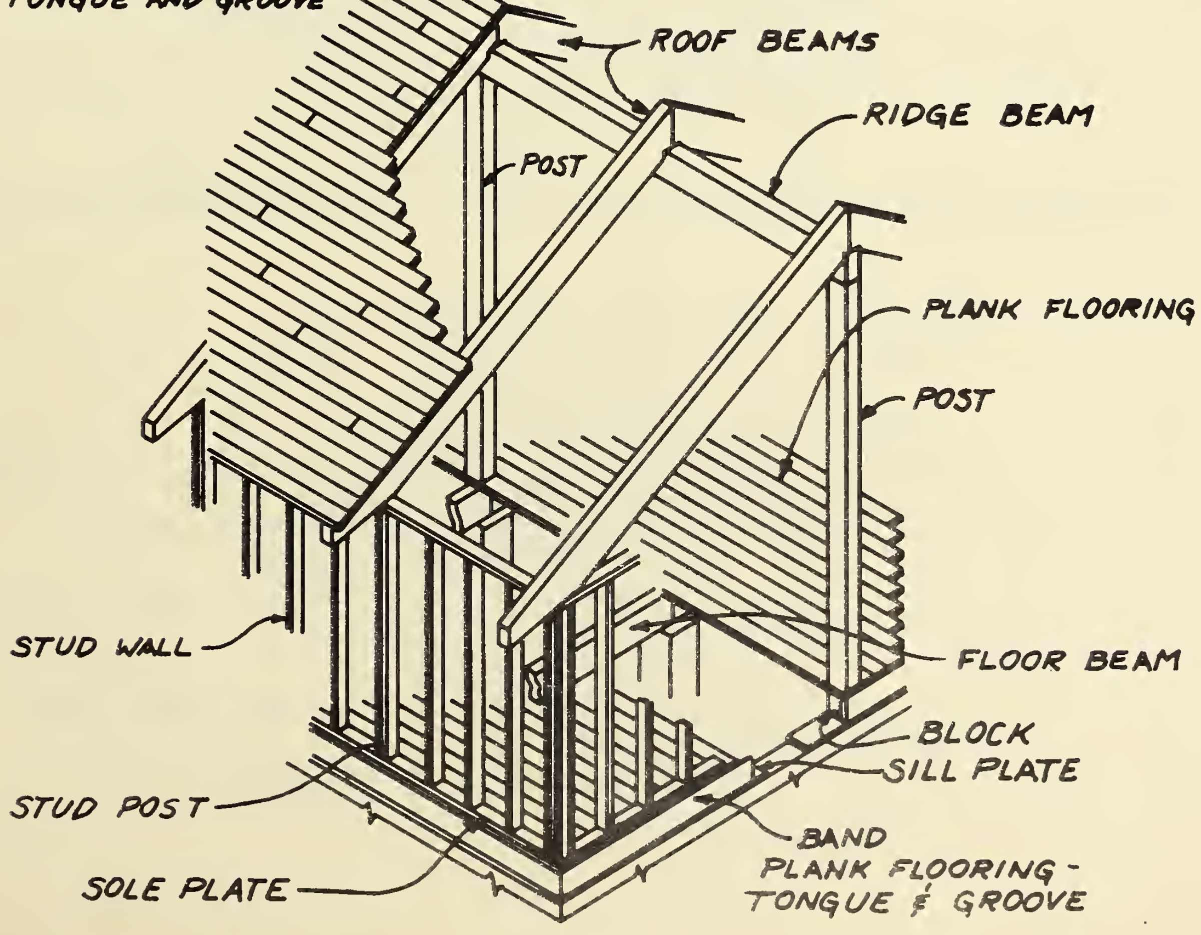

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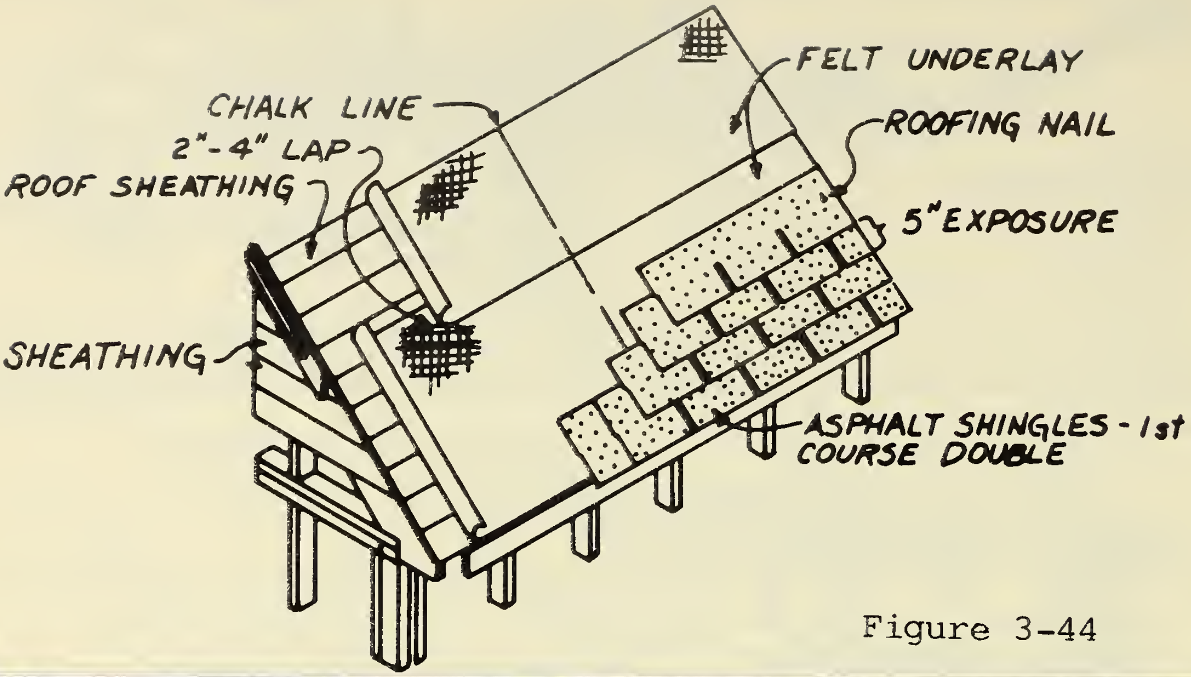

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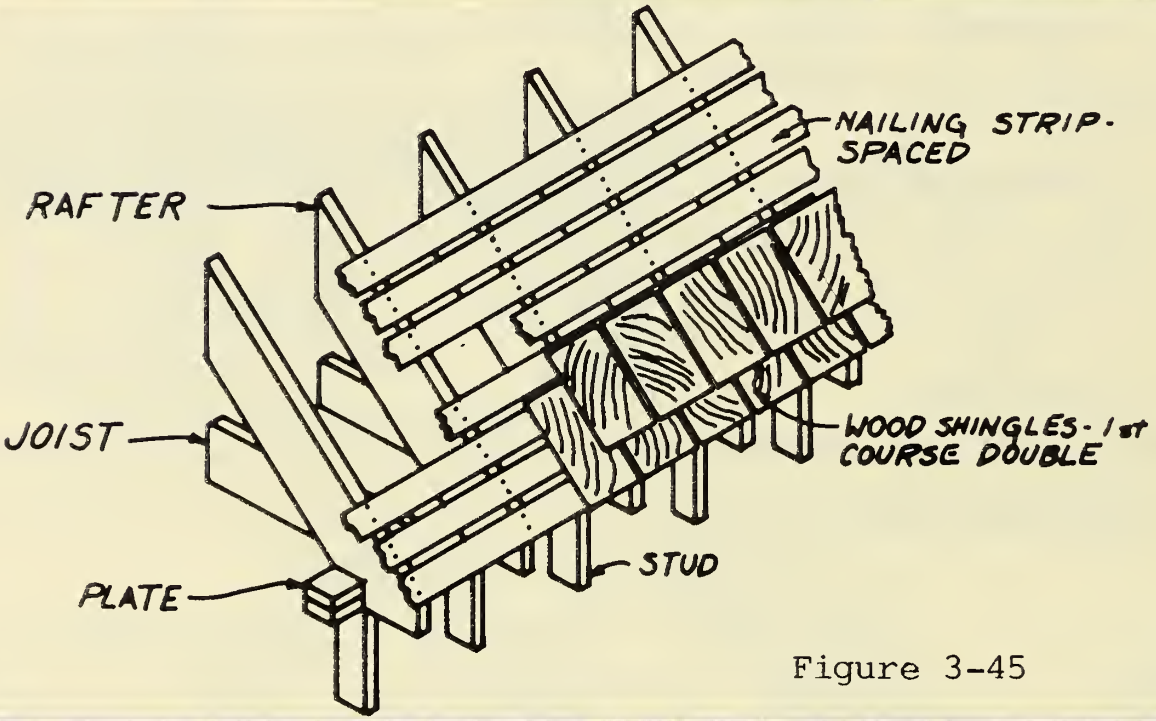

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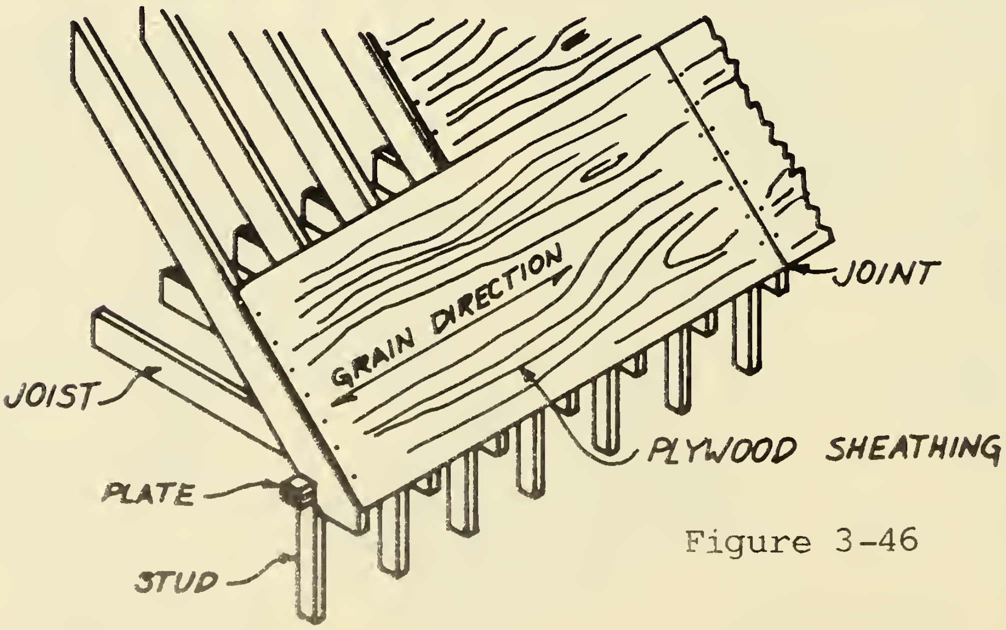

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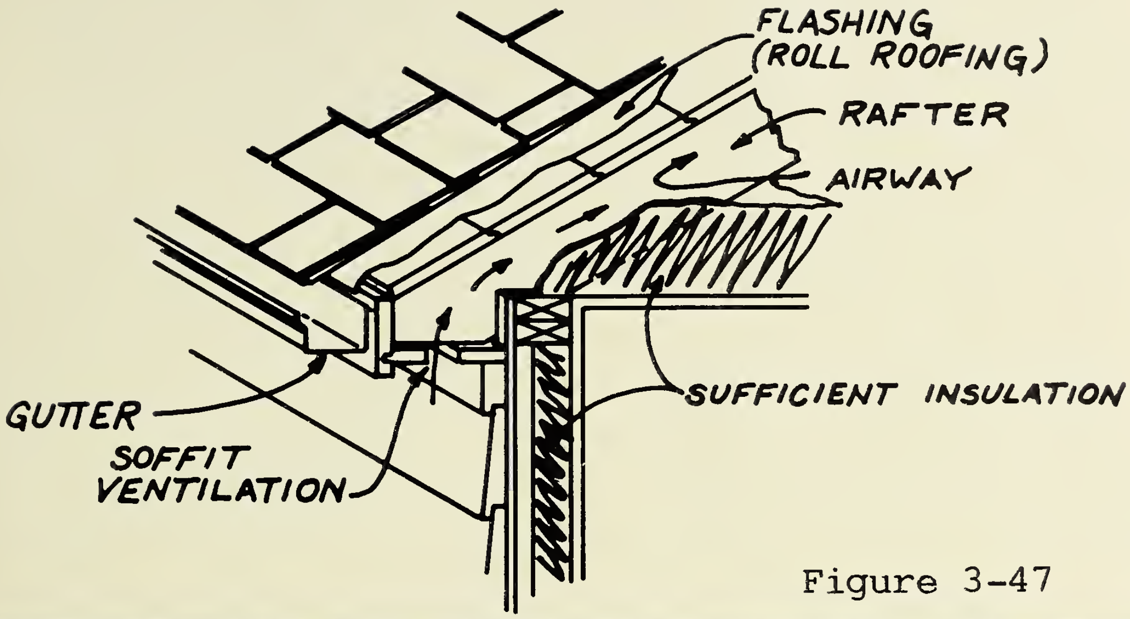

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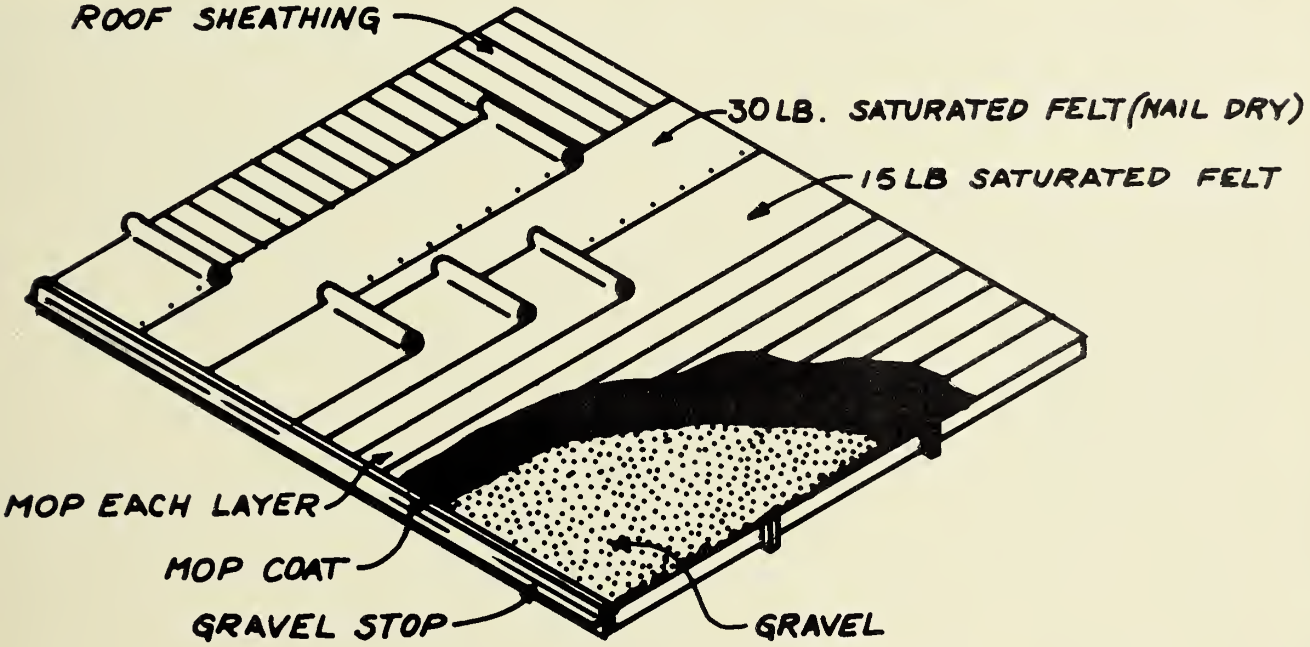


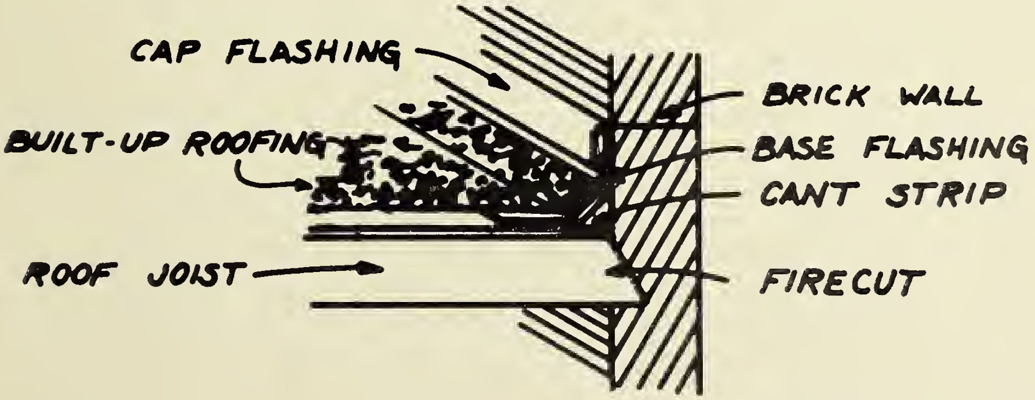


Figure 3-48

FLASHING DETAIL

CHAPTER IV
EQUIPMENT SYSTEMS

In addition to the structural system, the other major system in buildings is termed "equipment" since with current technology, almost all of the functions included are provided using technical solutions. However, many of these functions in the past were provided more simply.

Certainly today, the functions of a building involving heating, ventilating, cooling, lighting, plumbing, and energy distribution are equipment-based systems used to modify the natural environment. Another function, circulation, generally uses some equipment, in all but small buildings, even though the bulk of the function is provided through means used throughout history.

The nature of the means used to modify the natural environment has changed over the years from depending to a major extent on natural forces with limited modification, to great dependence on technology providing far greater modification. At the same time, the means available has changed in most cases from individual or point sources to area-wide or central systems. With increased use of technology has come increasing regulatory provisions in the Codes, especially in those functions whose use increases hazard from fire or disease.

HEATING

General

The function of the heating system in a building is to provide sufficient heat to the interior air and inner surfaces of enclosing construction to allow heat to flow from the occupants of the building at a rate at which they feel comfortable. If the temperature of the air and/or the surfaces surrounding the occupant is too low, heat is lost from the body too rapidly; if too high, heat is lost too slowly.

Thus, the nature of the enclosing surfaces is a major determinant of the amount of heat to be supplied for comfort and health. If the materials of the enclosing surfaces offer low resistance to the transfer of heat, heat flows toward the outside rapidly, cooling the air and providing cool surfaces. In turn body heat radiates toward the cool surfaces, therefore requiring the generation of more heat. Loose construction with many cracks or holes allows cold exterior air to enter, and additional heating is necessary.

The Housing Code establishes a criterion which requires that habitable space under ordinary minimum winter conditions have a temperature of 70° at 3 feet above the floor (the height of a child, or of a seated adult) for health reasons, since use of body energy to maintain temperature reduces the energy available to resist infection. In most sections of the United States, this criterion can only be met by the provision of some type of heating system.

Combustion

Combustion will occur, and continue, only if fuel is heated to the temperature at which ignition will occur, in the presence of oxygen. Remove fuel, heat, or oxygen, and combusion will cease. The temperature at which combustion of a fuel-and-air mixture will occur is the ignition temperature; heating appliances should maintain a burning temperature higher than the ignition temperature so combustion continues efficiently. In addition to heat, combusion produces water vapor and either carbon monoxide (toxic) or carbon dioxide.

If combustion is complete (adequate air is available), the full heating value of the fuel is obtained, with water vapor and carbon dioxide. If adequate air is not available, incomplete combustion occurs, less heat is obtained, and water vapor is produced with carbon monoxide. Carbon monoxide cuts off the oxygen from the tissues of the body, and without adequate ventilation, poisoning will occur. Low levels of carbon monoxide produce headaches, dizzy spells, drowziness, anemia, weakness, depression, irritability, vomiting, and circulatory impairment. Exposure to high levels, or low levels for a longer period, produces shortness of breath, convulsions, unconsciousness and coma, and possible death.

Because of the necessity to provide adequate supplies of air for complete combustion, and to remove by venting any dangerous gases resulting from combustion, the Codes have provisions for determining the volume of air to be supplied for combustion and venting, and for prohibiting use of unsafe unvented combustion equipment.

During the early years of American development, heating was accomplished by providing a heating device in each room or space to be heated. the centrally located fireplace and masonry chimney in small northern buildings provided heat directly only to the room in which it was located, but the heated gases moving up the chimney released their heat to the masonry which radiated warmth to the other spaces. Larger buildings, especially in the south, were more apt to have fireplaces and chimneys located on exterior walls. Since the only heating devices available involved combustion of fuels, chimneys or vents were required throughout the building. When the stove was developed into the furnace (or warm air) and the boiler (for water or steam), it became possible to provide a central source of heat and only one chimney was needed. Until the introduction of sheetmetal in economic form made alternatives available, masonry chimneys were required to exhaust the products of combustion.

The Code requires separation of combustible materials from fireplaces, chimneys and vents unless they have been tested and approved for less clearance. Chimneys and vents must permit proper draft, and be structurally safe, durable, smoke-tight, and capable of withstanding the action of flue gases. Mortars used in chimneys may have been eroded, and cracks opened up in the masonry, allowing flue gases to be diverted. Flue linings provide a smoother flow and greater protection from leakage, and must be provided for gas-fired equipment to be vented.

Chimneys

Masonry chimneys should be supported by an adequate foundation. The size of the chimney should at least provide enough space for the number and size of flues required. Each fireplace should have a separate flue, and more than two flues should be separated by a 4-inch-wide brick spacer (wythe) between them (Figure 4-1).

The greater the difference in temperature between chimney gases and outside atmosphere, the better the draft. Thus, an interior chimney will have better draft because the masonry will retain heat longer. The height of the chimney as well as the size of the flue are important factors in providing sufficient draft.

The height of a chimney above the roofline usually depends upon its location in relation to the ridge. The top of the extending flue liners should not be less than two feet above any portion of the roof or a wall within 10 feet (Figure 4-1), and the chimney should extend at least 3 feet above the highest point of the roof through which it passes. To prevent moisture from entering between the brick and flue lining, a cap is usually placed over the top course of brick (Figure 4-1). Precast concrete, or stone caps with a cement wash are also used.

Masonry chimneys should be separated from wood framing, subfloor, and other combustible materials. Framing members should have at least a 2-inch clearance and should be firestopped at each floor with asbestos or other types of noncombustible material (Figure 4-1). Subfloor, roof sheathing, and wall sheathing should have a ¾ inch clearance. A cleanout door is included in the bottom of the chimny where there are fireplaces or other solid fuel-burning equipment as well as at the bottom of th other flues, (Figure 4-1). The cleanout door for the furnace flue is usually located just below the smokepipe thimble with enough room for a soot pocket.

Rectangular fire-clay linings or round vitrified tile are normally used in masonry chimneys. Vetrified (glazed) tile or a stainless steel lining is required for gas-burning equipment. A fireplace chimney with at least an 8-inch thick masonry wall is not required to have a flue lining, and many existing chimneys do not have flue linings. A well-installed flue lining will result in a safer chimney.

To an inspector, on exterior inspection, peeling flue linings on the portion of the chimney above the roof will indicate trouble and a need for rebuilding. Exterior deterioration of the chimney will, if let go too long, gradually permit erosion from within the flues and eventually block the flue opening.

Rusted flashing at the roof level will also contribute to the chimney's deterioration. Efflorescence on the inside wall of the chimney below the roof and on the outside of the chimney. If exposed, will show salt accumulations—a tell-tale sign of water penetration and flue gas escape and a sign of chimney deterioration. In the spring and fall, during rain seasons, if terra cotta flues leak, the joint will be indicated by dark areas permitting actual counting of the number of flues inside the masonry chimney. When this condition occurs, it usually requires two or three months to dry out. Upon drying out, the mortar joints are discolored (brown), and after a few years of this type of deterioration the joints can be distinguished wet or dry. These conditions usually develop during coal operation and become more pronounced usually two to five years after conversion to oil or gas.

An unlined chimney can be checked for deterioration below the roof line by checking the residue deposited at the base of the chimney, usually accessible through a cleanout (door or plug) or breaching. Red granular or fine powder showing through coal soot or oil soot will generally indicate, if in quantity (a handful), that deterioration is excessive and repairs are needed.

Gas units attached to unlined chimneys will be devoid of soot, but will usually show similar tell-tale brick powder and deterioration as previously mentioned. Manufactured gas has a greater tendency than natural gas to dehydrate and decompose brick in chimney flues. For gas installations in older homes, utility companies usually specify chimney requirements before installation, and older chimneys may require the installation of terra cotta, stainless steel, or lead-lined copper liners, or transite pipe. Oil burner operation using a low air ratio and high oil consumption is usually indicated by black carbon deposits around the top of the chimney. Prolonged operation in this burner setting results in long carbon water deposits down the chimney for 4 to 6 feet or more and should indicate to the inspector a possibility of poor burner maintenance. This will accent a need to be more thorough on ensuing inspections. This type of condition can result from other related causes, such as improper chimney height or exterior obstructions such as trees or buildings, that will cause downdrafts or insufficient draft or contribute to a faulty heating operation.

Vents

Use of proper venting materials and correct installation of venting for gas-fired equipment is necessary to minimize harmful effects of condensation and to ensure that combustion products are carried off. All fuel-burning heating equipment must be vented, by Code. (Approximately 12 gallons of water are produced in the burning of 1,000 cubic feet of natural gas. The inner surface of the vent must therefore be heated above the dewpoint of the combustion products to prevent water from forming in the flue.) A horizontal vent must be given an upward pitch of at least ¼ inch per foot of horizontal distance.

When a vent or vent connector extends through floors or walls the metal pipe must be insulated from the floor or wall system by an air space (Figure 4-2) unless otherwise approved.

Avoid sharp bends (a 90° vent elbow has a resistance to flow equivalent to the length of a straight section 10 times the elbow diameter). Be sure the vent is of a rigid construction and resistant to corrosion by flue gas products. Several types of venting materials are available, such as types B and BW and several ceramic-type materials. A chimney lined with fire-brick type of terra cotta must be relined with an acceptable vent material if it is to be used for venting gas-fired appliances.

Use the same size vent pipe throughout its length. Never make a vent smaller than the equipment outlet except when two or more vents converge from separate heaters. To determine the size of vents beyond the point of convergence, the gas code should be used.

Insulation

Except in jurisdictions which have adopted energy conservation code provisions for existing buildings, the Codes contain no provisions requiring insulation in those surfaces of a building separating habitable space from external conditions. However, if insulation is installed, code provisions covering the materials and methods become relevent.

The inflow of heat through outside walls and roof in hot weather and its outflow during cold weather have important effects upon (a) the comforts of the occupants of a building and (b) the cost of providing either heating or cooling to maintain temperature at acceptable limits for occupancy. During cold weather, high resistance to heat flow also means a saving in fuel. While the wood in the walls provides good insulation, commercial insulation materials are usually incorporated into exposed walls, ceilings, and floors to increase the resistance to heat passage. The use of insulation in warmer climates is justified with air conditioning, not only because of reduced operating costs, but also because units of smaller capacity are required. Thus, whether from the stand-point of thermal comfort and heating costs in cold climates or for the benefit of reducing cooling costs, the use of insulation can certainly be justified.

Most materials used in houses have some insulating value. Even air spaces between studs resist the passage of heat. However, when these stud spaces are filled or partially filled with a material high in resistance to heat transmission, namely thermal insulation, the stud space has many times the insulating value of the air alone.

The thermal properties of most building materials are known, and the rate of heat flow or coefficient, U-value, is a measure of heat transmission between air on the warm side and air on the cold side of the construction unit. The insulating value of the wall will vary with different types of construction, with the materials used in construction, and with different types of thicknesses of insulation. Comparisons of U-Values may be made and used to evaluate different combinations of materials and insulation based on overall heat loss, potential fuel savings, influence on comfort and installation costs.

Commercial insulation is manufactured in a variety of forms and types, each with advantage for specifice uses. Materials commonly used for insulation may be grouped in the following general classes:

Flexible: blanket or batt of mineral wood or glass fiber (non-combustible), or vegetable fiber (combustible); used in framed construction primarily.

Loose Fill: mineral wood, glass fiber, vermiculite, perlite (non-combustible), or cellulosic, wood fiber or chips (combustible); used in framed or masonry construction.

Rigid: cellular glass (non-combustible), or foamed plastic, vegetable fiber (combustible); used in any type of construction.

Fluid: lightweight concrete or plasters (non-combustible), or foamed-in-place plastics (combustible); used in any type of construction.

Insulation is rated on its resistance or "R" value, and expression of its insulating value. The higher the "R" value, the better the insulating value. the reciprocal of the total "R" value is the overall heat loss value of all materials in the wall. The lower this value, the better the insulating value.

The use of storm windows or insulated glass will greatly reduce heat loss. For example, the "U" value of window glass is:

Glass	U Value
Single	1.13
With storm sash	0.53
Double Insulated, with ¼ inch air space	0.61

Almost twice as much heat loss occurs through a single glass as through a window glazed with insulated glass or protected by a storm sash. Furthermore, double glass will normally prevent surface condensation and frost forming on inner glass surfaces in winter. When excessive condensation persists, paint failures or even decay of wood sash rail or other parts can occur. Shading of glass against direct rays of the sun and the use of tinted and/or insulated glass will aid in reducing the air-conditioning load.

Precautions to be observed in the installation of insulating materials.

1. Continuity of the thermal insulating envelope should be provided by placing insulation in all areas of the enclosing surfaces (Figure 4-3), including around electrical outlet boxes, cables, and piping.
2. Combustible insulations cannot exceed maximum allowable flame spread or smoke development ratings.
3. Foam plastics must be provided with a thermal barrier from the interior space to protect the plastic from a rise in temperature for 15 minutes.
4. Cellulosic insulations depend on fire-retarding chemicals which may be dissolved and create corrosion-problems if subject to moisture, either from leaks or condensation.
5. Foam-in-place may fill voids in electrical outlet boxes (if improperly installed) and prevent dissipation of heat from the electrical conductors in the boxes.
6. Insulation surrounding electrical cables may also prevent heat dissipation from the cables, and cause fire.

Vapor Barrier

Most building materials are permeable to water vapor. This represents problems because considerable water vapor is generated in a house from cooking, dishwashing, laundering, bathing, humidifiers, and other sources. In cold climates during cold weather, this vapor may pass through wall and ceiling materials and condense in the wall or attic space; subsequently, in severe cases, it may damage the exterior paint and interior finish, or even result in decay in structural members. For protection, a material highly resistive to vapor transmission, called a vapor barrier, should be used on the warm side of a wall or below the insulation in an attic space (Figure 4-4).

Among the effective vapor-barrier materials are asphalt-laminated papers, aluminum foil, and plastic films. Most blanket and batt insulators are provided with a vapor barrier on one side, some of them with paper-backed aluminum foil. Foil-backed gypsum lath or gypsum boards are also available and serve as excellent vapor barriers. The flame spread and smoke development ratings of the vapor barrier must comply with Code requirements.

The perm values of vapor barriers vary, but ordinarily it is good practice to use those which have values less then ¼ (0.25) perm. Although a value of ½ perm is considered adequate, aging reduces the effectiveness of some materials.

Because no type of vapor barrier can be considered 100 percent resistive, and some vapor leakage into the wall may be expected, the flow of vapor to the outside should not be impeded by materials of relatively high vapor resistance on the cold side of the vapor barrier. For example, sheathing paper should be of a type that is waterproof but not highly vapor resistant. This also applies to "permanent" outer coverings or siding. In such cases, the vapor barrier should have an equally low perm-value. This will reduce the danger of condensation on cold surfaces within the wall.

Room Heating

Fireplaces have many disadvantages as means of heating space: wasteful (only 10% of the energy in the fuel provides heat to the occupants in a normal fireplace, somewhat higher in a circulating fireplace), messy, potentially dangerous, and limited in effectiveness which diminishes rapidly with distance. Improperly-designed or built fireplaces may not draw properly, or smoke may enter the room.

Careful attention should be given to the construction of the fireplace. Improperly built fireplaces are a serious safety and fire hazard (Figure 4-1). The most common causes of fireplace fires are thin walls, combustible materials such as studding or trim against sides and back of the fireplace wood mantels, and unsafe hearths. Fireplace walls should be not less than 8 inches thick, and if built of stone or hollow masonry units, not less than 12 inches thick. The faces of all walls exposed to fire should be lined with firebrick or other suitable fire-resistive material. When the lining consists of four inches of firebrick, such lining thickness may be included in the required minimum thickness of the wall. Steel angle iron is used to support the brick or masonry over the fireplace opening. Metal circulating fireplaces, which form the main outline of the opening and are enclosed with brick, are designed for proper functioning when flues are correct size.

Size of the flues is based on the face opening of the fireplace (width × height) and the shape or type of flue (Table 4-1).

For example, a fireplace opening of 36″ × 44″ has an area of 11.0 square feet, or 1584 square inches. If the chimney is lined with a round flue liner, it must have an area of 132 square inches, which would be provided by a 15" diameter flue. A square flue liner must have an area of 158.4 square inches, or 13 × 18. If the chimney were unlined, the flue needs an area of 198 square inches, or 12 × 17.

The back width of the fireplace is usually 6 to 8 inches narrower than the front. This helps to guide the smoke and fumes toward the rear. A vertical backwall of about a 14-inch height then tapers toward the upper section or "throat" of the fireplace (Figure 4-1). The area of the throat should be about 1-1/4 to 1-1/3 times the area of the flue to promote better draft. An adjustable damper is used at this area for easy control of the opening, and can be used to reduce heat loss up the chimney.

The smoke shelf (top of the throat) is necessary to prevent back drafts. The height of the smoke shelf should be 8 inches above the top of the fireplace opening (Figure 4-1). The smoke shelf is concave to retain any slight amount of rain that may enter.

The fireplace hearth should be constructed of brick, stone, tile, or similar incombustible material and should be supported on a fireproof slab or on a brick arch. If the opening is 6 square feet or more, the hearth should extend at least 20 inches beyond the chimney breast and not less than 12 inches beyond each side of the fireplace opening along the chimney breast; if less than 6 square feet, these dimensions should be 16 inches and 8 inches, respectively. The supporting construction of the hearth should be removed when construction is finished.

It is important that all wooden beams, joists, and studs are set off from the fireplace and chimney so that there is not less than two inches of clearance between the wood members and the sidewalls of the fireplace or chimney and not less than four inches of clearance between wood members and the back wall of the fireplace.

Stoves, being a point source of heat, have one of the disadvantages of the fireplace. They can be less wasteful of fuel, safer if properly installed and protected, and more effective in distributing heat. Metal chimneys or vents must be sized properly, and installed with required clearances from combustible materials. Stoves can be located no closer to combustible materials than shown in the approval listing. Hearth extensions must be non-combustible materials at least ⅜" thick but can be supported directly on the floor construction, if distinguishable from the surrounding flooring.

Space Heaters

Space unit heaters are the least desirable from the viewpoint of fire safety and housing inspection. All space unit heaters must be vented to a flue, unless listed otherwise.

Coal-fired space heaters (Cannon Stove) are made primarily of cast Iron (Figure 4-5). In operation, coal on the grates receives primary air for combustion through the grates from the ash-door draft intake. Combustible gases driven from the coal by the heat burn in the barrel of the stove, where they receive additional or secondary air through the feed door. The side and top of the stove absorb the heat of combustion and radiate it to the surrounding space.

Oil-fired space heaters have atmospheric vaporizing-type burners. The burners require a light grade of fuel oil that vaporizes easily and is comparatively low in temperature. In addition, the oil must be such that it leaves only a small amount of carbon residue and ash within the heater. Oil-fired space heaters are basically of two types: The perforated-sleeve burner consists essentially of a metal base formed of two or more angular fuel-vaporizing bowl burners and is widely used in space heaters and some water heaters. (Figure 4-6a). The pot-burner (Figure 4-6a) consists essentially of a bowl, 8 to 13 in. in diameter, with perforations in the side that admit air for combustion. The upper part of the bowl has a flame ring or collar. When several space heaters are installed in a building, an oil supply from an outside tank to all heaters is often desirable.

Gas room heaters and wall furnaces are normally made from sheet metal, with an enclosure which allows room air and/or outside air to enter to be heated. The gas burner, generally with a pilot for ignition, is within the enclosure, and should have a valve shutoff in the event the flame of the pilot or the burner is extinguished. Direct vented heaters (or sealed combustion system) are so installed that adequate combustion air and venting are provided.

The One-and-Two Family Dwelling Code (developed by the model code organizations) prohibit the installation of combustion heating devices in a bedroom or bathroom, or a closet opening to either.

Central Heating Systems

GENERAL

Development of central heating systems was first based on gravity-flow (the natural tendency of a heated fluid to rise, and a cooler fluid to fall) which created obvious limitations on the size and efficiency of the systems, especially warm-air systems. Hot water and steam were more efficient gravity systems. With the introduction of electric motors, blowers or fans to move air and pumps to move water or create a vacuum became feasible, and most of the limitations were overcome; with the development of automatic controls (thermostats, aquastats, timers, and pressure regulators) more limitations were removed.

Boilers and furnaces, other than for one-and-two family dwellings, must be in a room separated from the rest of the building by fire-rated construction, if they have an input capacity of 250,000 BTU or there are 75 or more occupants. In many cases, enclosing the furnace or boiler may create a problem of providing adequate air for combustion and venting, and must meet Code requirements. The surfaces of the room enclosing the boiler or furnace must meet certain clearances (Figure 4-7). In rehabilitation inspection, however, we are dealing with existing conditions; therefore, we must adapt the situation as closely as possible to acceptable safety standards. In many old buildings the furnace is located in the center of a cellar or basement, and this location does not lend itself for practical conversion to an equipment room.

WARM-AIR

Heating furnaces, the heat sources used when air is the heat-carrying medium, may be of cast iron or steel and burn various types of fuel.

Gravity-warm-air heating systems operate because of the difference in specific gravity of warm air and cold air. Warm air is lighter than cold air and rises if cold air is available to replace it (see Figure 4-8).

Satisfactory operation of a gravity-warm-air heating system depends on three factors. They are: (1) size of warm and cold air ducts, (2) heat loss of the building, and (3) heat available from the furnace.

The most common source of trouble in these systems is having insufficient pipe area, usually in the return or cold air duct. The total cross-section area of the cold duct or ducts must be at least equal to the total cross-section of all warm ducts.

The simplest type is the floor furnace suitable for small homes where all rooms can be grouped about a single large register. The most common difficulty experienced with this type of furnace is supplying a return air opening of sufficient size on the floor.

The forced warm-air furnace is the most modern type of warm-air equipment (see Figure 4-9a). It is the safest type because it operates at low temperatures. The principle of a forced-warm-air heating system is very similar to that of the gravity system, except that a fan or blower is added to increase air movement. Because of the assistance of the fan or blower, the pitch of the ducts or leaders can be disregarded and it is therefore practical for delivering heated air in the most convenient places (Figure 4-9b).

In a forced-air system, operation of the fan or blower must be controlled by air temperature in a bonnet or by a blower control furnacestat. The blower control starts the fan or blower when the temperature reaches a certain point and turns the fan or blower off when the temperature drops to a predetermined point.

Dampers in the various warm-air ducts control distribution of warm air either at the branch takeoff or at the warm-air outlet.

Humidifiers are often mounted in the supply bonnet in order to regulate the humidity within the residence.

The crawl space plenum system is a recent-approved modification of the forced warm-air system in which the ductwork leading.from the bonnet of the furnace to the supply registers (Figure 4-9c) are replaced by using the crawl space under the floor as a plenum or pressurized chamber. As shown in Figure 4-9c, a down flow furnace is used to supply air into the crawlspace. In order to conserve energy and reduce heat loss, the walls of the crawlspace must be insulated as thoroughly as though they enclosed habitable space, and the earth of the lower surface must be covered with a good vapor barrier to reduce introduction of ground moisture into the house. Ventilation of the crawlspace may be omitted.

In the rehabilitation of one story structures, this system may prove the simplest means of providing an up-to-date heating system since it avoids the problems of installing ductwork. Addition of skirting between the floor and ground could be used to create a crawlspace for buildings supported on piers, if adequate clearance can be provided.

A forced air system not only provides heating, but can also provide cooling with the addition of cooling units, if the system is properly designed.

Hot Water and Steam

BOILERS

The term boiler is applied to the single heat source that can supply either steam or hot-water (a boiler is often called a heater).

All boilers have a combustion chamber for burning fuel. Automatic fuel-firing devices help supply the fuel and control the combustion. Handfiring is accomplished by the provision of a grate, ash pit, and controllable drafts to admit air under the fuel bed and over it through slots in the firing door. A check draft is required at the smoke pipe connection to control chimney draft. The gas passes from the combustion chamber to the flue passages which are designed for maximum possible transfer of heat from the gas. Provisions must be made for cleaning flue passages.

Boilers may be classified according to several kinds of characteristics. The material may be cast iron or steel. Their construction may be section, portable, fire-tube, water-tube, or special. Domestic heating boilers are generally of low-pressure type with a maximum working pressure of 15 pounds per square inch for hot water.

Cast iron boilers are generally classified as square or rectangular boilers with vertical sections, or round, square, or rectangular boilers with horizontal pancake sections. Cast iron boilers are usually shipped in sections and assembled at the site.

Most steel boilers are assembled units with welded steel construction and are called portable boilers. Larger boilers are installed in refractory brick settings built on the site. Above the combustion chamber a group of tubes is suspended, usually horizontally, between two headers. If flue gases pass through the tubes and water surrounds them, the boiler is designated as the fire-tube type, the predominant type. When water flows through the tubes, it is termed water-tube.

STEAM HEATING

Steam heating systems are classified according to the pipe arrangement, accessories used, method of returning the condensate to the boiler, method of expelling air from the system, or the type of control employed. The successful operation of a steam heating system consists of generating steam in sufficient quantity to equalize building heat loss at maximum efficiency, expelling entrapped air, and returning all condensate to the boiler rapidly. Steam cannot enter a space filled with air or water at pressure equal to the steam pressure. It is important, therefore, to eliminate air and to remove water from the distribution system. All hot pipe lines exposed to contact by occupants must be properly insulated or guarded.

The gravity one-pipe air-vent system was one of the earliest types used. The condensate is returned to the boiler by gravity. This system is generally found in one building heating systems. The steam is supplied by the boiler and carried through a single system or pipe to radiators as shown in Figure 4-10a. Return of the condensate is dependent on hydrostatic head. Therefore, the end of the steam main, where it attaches to the boiler, must be full of water (termed a wet return) for a distance above the boiler line to create a pressure drop balance between the boiler and the steam main.

Radiators are equipped with an inlet valve and with an air valve. The air valve permits venting of air from the radiator and its displacement by steam. Condensate is drained from the radiator through the same pipe that supplies steam.

The two-pipe vapor system with boiler return trap and air eliminator is an improvement of the one-pipe system. The return connection of the radiator has a thermostatic trap that permits flow of condensate and air only from the radiator and prevents steam from leaving the radiator. Since the return main is at atmospheric pressure or less, a boiler return trap is installed to equalize condensate return pressure with boiler pressure.

HOT WATER HEATING

All hot water systems are similar in design and operating principle.

The one-pipe gravity hot water heating system is the most elementary of the gravity systems and is shown in Figure 4-10b. Water is heated at the lowest point in the system. It rises through a single rise or radiator branch take off from the top of the main to supply water to the radiators. After the water gives up heat in the radiator it goes back to the same main through return piping from the radiator. This cooler return water mixes with water in the supply main and causes the water to cool a little. As a result, the next radiator on the system has a lower emission rate and must be larger.

Note in Figure 4-10a that the high points of the hot water system are vented and the low points are drained. In this case, the radiators are the high points and the heater is the low point.

A one-pipe gravity system becomes a two-pipe system if the return radiator branch connects to a second main that returns water to the heater (see Figure 4-10c). Water temperature is practically the same in all the radiators.

In a one-pipe forced-feed system a pump or circulator is introduced in the main near the heater of the one-pipe system, providing a system that can be used for much larger applications than the gravity type. This system can operate at higher water temperatures than the gravity system. The faster moving higher temperature water makes a more responsive system with a smaller temperature drop through each radiator. Higher operating temperatures and lower temperature drops permit the use of smaller radiators for the same heating load.

A two-pipe forced-circulation system is similar to a one-pipe forced-circulation system except that the piping arrangement is the same as in the two-pipe gravity flow system.

When water is heated it tends to expand. Therefore, in a hot water system an expansion tank is necessary. The expansion tank, either of open or closed type, must be of sufficient size to permit a change in water volume within the heating system. If the expansion tank is of the open type it must be placed at least 3 feet above the highest point of the system. It will require a vent and an overflow. The open tank is usually in an attic, where it needs protection from freezing.

The enclosed expansion tank is found in modern installations. An air cushion in the tank compresses and expands according to the change of volume and pressure in the system. Closed tanks are usually at the low point in the system and close to the heater. They can, however, be placed at almost any location within the heating system.

LIGHTING

Natural

Daylight shold be used as fully as possible in all buildings no matter how adequate other forms of light may be. Satisfactory natural illumination depends upon the intensity of daylight or sky brightness and the amount, distribution, and quality of this light in a room. Natural light is particularly important in low-income housing where, due to cost, artificial lighting will be held to a minimum. Light is important in showing up dirt and thus leads to more cleanliness within the home, although the bactericidal effect of light transmitted through glass is questionable.

The lighting requirements in the Code shall be deemed satisfactory if every habitable room has one window facing directly to the outdoors and the total window area in each habitable room is at least eight percent of the floor area of that room. In computing window areas, no deduction is made for sashes and trim used to hold the glass panes in place. Note here that a window located less than 3 feet from an outside wall or other structure that extends above the ceiling level of the room is not deemed to face directly outdoors. A window that faces directly into a completely enclosed court is counted as facing directly to the outdoors as long as the court is greater than three feet in its least dimension.

If a skylight type of window in the ceiling of the habitable room serves as the only window in the room, the area of the horizontal projection of the skylight should be at least 15 percent of the total floor area of the room. In a room with both a window and a skylight, the total area of both should be at least 10 percent of the floor area.

For example, a 10′ x 18′ room, with area of 180 square feet, needs a window area of 14.4 square feet, or 3′0″ x 4′-9½″; skylight area would need to be 27 square feet or 3′0″ x 9′0″. However, a 2′6″ x 4′0″ window and a 3′0″ x 3′0″ skylight would also be acceptable.

Windows are the primary means of providing for daylight and air to enter the rooms of a building, but they may also be an important part of the architectural design.

Today windows and their frames are items that are usually fully assembled at the factory, in the past they were frequently site-built. Window units, for example, often have the sash fitted and weather-stripped, frame assembled, and exterior casing in place. Standard combination storms and screens or separate units can also be included. They may be made of wood or metal. Heat loss through metal frames and sash is much greater than through similar wood units. Glass blocks are sometimes used for admitting light in places where transparency or ventilation is not required.

Insulated glass, used both for stationary and moveable sash, consists of two or more sheets of spaced glass with hermetically-sealed edges. This type has more resistance to heat loss than a single thickness and is often used without a storm sash.

Wood sash and door and window frames should be made from a clear grade of all-heartwood stock of a decay-resistant wood species or from wood which is given a preservative treatment. Species commonly used include ponderosa and other pines, the cedars, cypress, redwood, and the spruces.

Windows are available in many types, each having advantages. The principal types are double-hung, casement, stationary, awning, and horizontal sliding (Figure 4-11). All types of windows should open freely and close securely.

The double hung window is perhaps the most familiar window type. It consists of upper and lower sashes that slide vertically in separate grooves in the side jambs or in full-width metal weather-stripping. This type of window provides a maximum face opening for ventilation of one-half the total window area. Each sash is provided with springs, balances, or compression weatherstripping.

The principal parts of a double-hung window (see Figure 4-12) are the lights, the top railframing members, bars or muntins that separate the lights, stiles-side-framing members, bottom rail, sash weights, and sash cords or chains. (All rails are horizontal, all stiles vertical.) The exterior sill is the bottom projection of a window. The drip cap is a sparate piece of wood projecting over the top of the window and is a component of the window casing.

Casement windows consist of side-hinged sash, usually designed to swing outward because this type can be made more weathertight than the in-swinging style. Screens are located inside these out-swinging windows, and winter protection is obtained with storm sash or by using insulated glass in the sash. One advantage of the casement window over the double-hung type is that the entire window area can be opened for ventilation. A casement windows' principal parts include top and bottom rails, muntins, stiles, butt hinges, and jamb.

Stationary or fixed windows usually consist of a frame and glazed stationary sash. They are often flanked with double hung and casement windows, or stacked with awning and hopper units, to make windows of custom designs.

An awning window unit consists of a frame in which one or more operative sashes are installed. Sashes of the awning type are made to swing outward at the bottom. A similar unit, called the hopper type, is one in which the top of the sash swings inward. Both types provide protection from rain when open.

Horizontal-sliding windows appear similar to casement sash. However, the sash (in pairs) slide horizontally in separate tracks or guides located on the sill and head jamb.

Windows must be weathertight, watertight, and rodent proof and be kept in good working condition. They must be fully glazed, without cracks or holes, and must have screens.

Artificial

For those periods when daylighting is insufficient to meet the needs of the occupants, artificial light must be provided. In the majority of cases, electricity is the energy source used. However, gas illumination may be used, primarily for decorative purposes. If gas is used, listed illuminating appliances must be used, installed properly and attached to structural supports so that they do not depend on the gas piping for support.

Natural light through windows does not penetrate deeply into a building (about 15 feet). Obviously, less energy is used by natural light, and cooling loads may be lower. In addition, natural light is more diffuse with a better quality, so that more foot candles of artificial light are needed to provide equivalent illumination. The efficiency of artificial lighting in terms of electrical energy used depends on the amount of light (in lumens) provided per watt of electrical energy.

Every water closet compartment, bathroom, laundry room, furnace room, and public hall shall contain at least one supplied ceiling or wall-type electric light fixture. Convenient switches or equivalent devices for turning on one light for each room or passageway should be located so as to permit the area ahead to be lighted.

Every public hall and stairway in a multiple dwelling shall be adequately lighted by natural or electric light or both at all times so as to provide in all parts at least one foot candle of light at the tread or floor level. If the structure contains not more than two dwelling units this light may be controlled by a switch and be turned on when needed, instead of being turned on full time.

VENTILATING

General

Adequate ventilation is essential in meeting many of the fundamental needs in housing. Among these are the maintenance of a thermal environment that will permit adequate heat loss from the human body, provision of an atmosphere of reasonable chemical purity, and provision of possibilities for aesthetic satisfaction in the home and its surroundings.

The factors controlling heat loss in the body are air temperature, mean radiant temperature of surrounding surfaces, relative humidity, and air movement. It is particularly important that moving air be made available in sleeping rooms since its impact is of great value in promoting healthful sleep. Moreover, odors given off by the body exert a definitely harmful influence on appetite and therefore upon health. There can be no doubt that the well-ventilated home, like the well-illuminated home, is more conductive to healthful mental attitudes than the poorly ventilated or poorly illuminated home.

Ventilation of Habitable Space

The code requirement for ventilating a habitable room is 45 percent of the required window area in the Housing Code and 50% in the Building Code, except where an approved mechanical means of ventilation is installed providing two air changes per hour.

Every bathroom and toilet room should comply with the Code ventilation requirements for habitable rooms except that windows or skylights are not required if the ventilation system is adequate, and provides at least five changes of air per hour.

The capacity of the ventilating system can be calculated by dividing the volume of the room in cubic feet by 60 minutes/hour, and multiplying the result by the number of changes needed, or $\mathrm{Cap} = \frac{\mathrm{LxWxHxAC}}{60}$.

If the bathroom has a floor area of 30 square feet and a ceiling height of 8 feet, the volume is 240 cubic feet. Dividing by 60, and multiplying by 5 air changes indicates a capacity required of 20 cfm (cubic feet per minute).

As has been previously mentioned, light promotes cleanliness, which is particularly important in bathrooms and toilet rooms, where cleanliness is essential to sanitation and proper attitudes are essential to cleanliness.

Ventilation is also necessary in these rooms because they are subject to a high concentration of body odors and humidity. Since these rooms are frequently located, for economical construction reasons, within the inner part of the structure and away from the exterior walls, windows and skylights are not always practical. The provision of artificial light sources and mechanical ventilation will, therefore, accomplish the basic purposes of light and ventilation requirements, and at the same time meet practical standards of construction.

In addition to these ventilation requirements, use of combustion equipment for heating or cooling requires air for combustion and venting. This was not a great problem in the past, because the construction of many buildings provided adequate infiltration through cracks and holes. Tighter construction may create problems of adequate air, and the combustion devices may use the oxygen in the air needed for life by the occupants, or, more seriously, may not have complete combustion and generate carbon monoxide in the building.

Ventilation of Non-Habitable Space

A third type of ventilation required in the Codes is for removing moisture from the normally non-habitable areas under a building, in the crawl space, and in attic and roof construction. Condensation of moisture vapor may occur in attic spaces and under flat roofs during cold weather. Even where vapor barriers are used, some vapor will probably work into these spaces around pipes and other inadequately protected areas and some through the vapor barrier itself. Although the amount might be unimportant if equally distributed, it may be sufficiently concentrated in some cold spot to cause damage. While wood shingle and wood shake roofs do not resist vapor movement, such roofings as asphalt shingles and built-up roofs are highly resistant. The most practical method of removing the moisture is by adequately ventilating the roof spaces.

A warm attic that is inadequately ventilated and insulated may cause formation of ice dams at the cornice. During cold weather after a heavy snowfall, heat causes the snow next to the roof to melt. Water running down the roof freezes on the colder surface of the cornice, often forming an ice dam at the gutter which may cause water to back up at the eaves and into the wall and ceiling. Similar dams often form in roof valleys. Ventilation provides part of the answer to the problems. With a well-insulated ceiling and adequate ventilation, attic temperatures are low and melting of snow over the attic space will be greatly reduced.

In hot weather, ventilation of attic roof spaces offers an effective means of removing hot air and thereby materially lowering the temperature in these spaces. Insulation should be used between ceiling joists below the attic or roof space to further retard heat flow into the rooms below and materially improve comfort conditions.

It is common practice to install louvered openings in the end walls of gable roofs for ventilation. Air movement through such openings depends primarily on wind direction and velocity, and no appreciable movement can be expected when there is no wind or unless one or more openings face the wind. More positive air movement can be obtained by providing openings in the soffit areas of the roof overhang in addition to openings at the gable ends or ridge. Hip-roof houses are best ventilated by inlet ventilators in the soffit area and outlet ventilators along the ridge. The differences in temperature between the attic and the outside will then create an air movement independent of the wind, and also a more positive movement when there is wind.

Tight construction (including storm windows and storm doors) and the use of humidifiers have created potential moisture problems which must be resolved through planning of adequate ventilation as well as the proper use of vapor barriers. Blocking of ventilating areas, for example, must be avoided, as such practices will prevent ventilation of attic spaces. Inadequate ventilation will often lead to moisture problems which can result in unnecessary costs to correct, or unsatisfactory conditions such as decay, mildrew, and similar concerns.

Types of ventilators and minimum required sizes have been generally established for various types of roofs. The minimum net area for attic or roof-space ventilators is based on the projected ceiling area of the rooms below. The ratio of ventilator openings are net areas, and the actual area must be increased to allow for any restrictions such as louvers and wire cloth or screen. Attics without a ceiling vapor barrier must be ventilated with one square foot of vent area for each 150 square feet of ceiling. Attics with a ceiling vapor barrier must be ventilated with one square foot of vent area for each 300 square feet of ceiling.

A ceiling area of 1500 square feet would require 10 square feet of vent area if there were no vapor barrier (which would be best provided with 5 square feet along the eaves and 5 square feet in the gable ends) but only 5 square feet with a vapor barrier.

A greater ratio of ventilating area is required in some types of flat roofs than in pitched roofs because the air movement is less positive and is dependent upon wind. It is important that there be a clear open space above the ceiling insulation and below the roof sheathing for free air movement from inlet to outlet openings. Solid blocking should not be used for bridging or for bracing over bearing partitions if its use prevents the air circulation.

Where there is a crawl space under the house or porch, ventilation is necessary to remove moisture vapor rising from the soil. Such vapor may otherwise condense on the wood below the floor and facilitate decay. A permanent vapor barrier on the soil of the crawl space greatly reduces the amount of ventilating area required.

The crawl space below the floor of the basementless house and under porches should be ventilated and protected from ground moisture by the use of a soil cover (Figure 4-13). The soil cover should be a vapor barrier with a perm value of less than 1.0. This includes such barrier materials as plastic films, roll roofing, and asphalt laminated paper. Such protection will minimize the effect of ground moisture on the wood framing members. High moisture content and humidity encourage staining and decay of untreated members.

The Code requires provision of cross-ventilation, with a total net area of all openings of 1 square foot per 150 square feet of crawlspace area for wood construction, or 1½ square feet of opening per 15 linear foot of perimeter wall for other materials. If the soil covers discussed above are used, 10 percent of the above required area is acceptable.

The 1500 square foot framed house would need 1500/150 or 10 square feet of openings distributed around the perimeter, but only 1 square foot if groundcover were used. If a 1500 square foot masonry house had a perimeter of 50′ x 30′ or a total of 160 linear feet 160/15 = 10.67 x 1½ = 16 square feet of opening but only 1.6 square feet if ground cover were used.

PLUMBING

General

The plumbing systems now found in buildings represent in most basic form, hygiene facilities which have always been more or less the same: a container for holding water for washing, and a container for holding body wastes which were ultimately disposed of in one of two ways — by returning to the soil or by washing away with water. Depending on the spirit of the age, the accommodations were more or less sophisticated. At times the containers have been permanently incorporated into the construction and supplied with running water and water-flushed sewage systems; at other times the containers were portable utensils and water was pumped or carried, and wastes were simply dumped.

Until comparatively recent times the most commonly found facilities were simply portable containers that came in a wide variety of shapes, sizes, and degrees of luxury, depending on the station of the user and the age in which he lived. The growth of permanent communities, however, ultimately necessitated centralized water supplies and a method of waste disposal more sanitary and efficient than simply dumping slop buckets out the window, though this was a common practice in cities for centuries. The continued growth of cities forced the develpment of a common water-borne sewage system, particularly after it was recognized that disease and epidemics could spread rapidly throughout an urban population as long as unsanitary conditions prevailed. It was also inevitable that means would be devised to connect the containers in the households and buildings directly to the system and thus end the carrying of water and wastes to and from the outlets of the central systems.

Once the connections to a general system were made, it was possible to have permanent fixtures placed within houses and buildings. By the end of the ninteenth century, installed hygiene facilities, very much in the form that we know today, began to be found in more and more middle-class homes, at least in the urban areas. The chief concern was to have the waste products disposed of in such a manner that the health of communities would be protected. This concern still poses some of the most pressing problems in many rapidly expanding urban concentrations because of large numbers of people living in close proximity in more or less permanent locations.

The Codes require that every building used for human occupancy must be provided with an adequate supply of water approved for human use.

The tighter the density of living arrangements, the more important personal habits become to the group. Virtually all new residential construction, at least in urban areas, has been required by law to include as the minimum a private bath for each dwelling unit.

Plumbing systems in buildings being rehabilitated maydeviate from current provisions if these deviations conform to the intent of the Code, do not involve health or safety hazards, and if any sections with excessive wear, damage or other defects are replaced.

The plumbing systems in buildings today serve three major purposes: water distribution, drainage, and venting.

Water Distribution System

Water distribution systems are those systems of piping and equipment within a building which transfer water from the community distribution system to the several points of use throughout the building. In·earlier days, and still in remote locations, the source of water may be a private source such as a well. In addition to piping, certain equipment is required: a meter, a pressure-reducing valve, a water heater for hot water, a pump if the building is taller than pressure will serve or if a private source is used, and the various fixtures and appliances which provide access to the water at the point-of-use.

The distribution of water through buildings implies a system of piping which is efficient for its purpose, easily maintained, and interferes with other components of the building as little as possible. Normally, most of the system is now concealed, although in older buildings much more will be exposed. In woodframe construction, concealment is readily provided but must be inspected to ensure that fire safety and durability of the structure have not been compromised. Generally, in more fire-resistive construction, vertical and horizontal chases must be provided; penetrations of floors or walls may have voided the fire-resistance of those surfaces.

Many of the waters used in the United States may have corrosive effects on the materials used in the distribution system, or may cause desposits ("scale") within the piping which ultimately reduce the capacity of the piping to transport the necessary volume of water. Water treatment can be used to prevent these problems, but will be of little use if the problem has existed for some period of time.

Materials used in water distribution systems, approved in the Plumbing Code, are galvanized or stainless steel, cast iron pressure pipe, copper or brass, and chlorinated polyvinyl chloride or polybutylene plastic piping. In the assembly of pipe or tubing into a system, various fittings are required to connect separate lengths, change direction, or provide control of water pressure temperature, or flow. These fittings should be of materials compatible with the piping materials. Piping and fittings must be installed in a neat manner and be watertight; piping cannot be installed in an exterior wall or outside the building unless protected from freezing. Piping must be installed to avoid strain and stress, with provision for expansion, contraction, and settlement of the building structure. Support for pipes or tubing should not weaken the structural system.

Each dwelling unit must have an adequate supply of both cold and hot water. Each dwelling must have water heating facilities installed and maintained in a safe and good working condition, that are capable of heating water to a temperature of 120° F to permit an adequate amount of water to be used at the sink, wash basin, and bathtub or shower. Thirty gallons of water storage should be the minimum available whether the space heating system is in operation or not.

Water heaters are usually powered by electricity, fuel oil, gas, or in rare cases, coal or wood. They consist of a space for heating the water and a storage tank for providing hot water over a limited period of time.

All water heaters should be fitted with a temperature-pressure relief valve no matter what fuel is used, and be installed in accordance with their listing. This valve will operate when either the temperature or the pressure becomes too high due to an interruption of the water supply or a faulty thermostat.

Figure 4-14 shows the correct installation of a hot water heater. There must be a means of disconnecting the energy source from the heater, and a means of draining the unit, through an indirect waste drain.

Since only potable water can be used for drinking, cooking, bathing and similar purposes, the water outlets must have provisions to prevent backflow and contamination of the water.

Piping must be properly sized to provide an adequate supply of water at adequate pressure for the fixtures and other outlets, using good engineering practice. Allowances are made in the calculations for pressure loss due to friction of the flow of water through the system. However, deposits of minerals in the water on the inside surfaces will reduce the available volume of the piping over a period of years, and samples of the piping should be examined to determine adequacy for continued use. Code provisions govern the minimum size.

In high-rise structures, it may be necessary to pump or use tanks to supply water to the upper floors.

Drainage System

The water supply brought into a building must be discharged quickly and quietly from the building through the drainage system following its use to avoid nuisance and risk of injury to health. A building may have two systems, one for sanitary, the other for storm drainage, but the two systems must be separate within the building, and the piping used for one cannot be used for the other. In addition to discharging water, the drainage system must also rapidly dispose of the organic fluid and solid wastes resulting from human occupancy.

In general, the qualities desirable are durability, resistance to shock or mechanical damage, smooth and flush interior surfaces, and resistance to corrosion and electrolytic erosion. The several components of the system are shown in Figure 4-15, and must be of suitable size to convey their contents at sufficient velocity to prevent fouling or clogging. Materials used and approved in current Codes include cast iron soil pipe, lead, copper, and plastic DWV pipe; with fittings of compatible materials.

The layout of the piping must be much straighter and more direct than that of the water distribution piping for two reasons. First, water supply is generally under pressure, whereas drainage flows by gravity. Second, drainage piping carries solids as well as water and generally conducts a larger volume at the time of use, since it is intermittent in use. For this last reason, pipe sizes must be considerably larger than supply piping, and because of being a gravity system, the slope of the lines is critical (Figure 4-15): if too steep, the liquid portion of the waste fails to carry the solids with it; if too flat, no scouring occurs, and solid waste is deposited. Generally, 1/8" to 1/4" per foot fall is used, although the actual slope varies with the diameter of the pipe. If solid materials, of any nature, should remain in the drainage piping for any reason, blockage of the line may result. The Code requires accessible cleanouts at each change in direction.

Sizing of drainage piping is based on the expected rate of discharge of the waste from each type of fixture, and the Code bases the size on the "fixture unit" rating of each fixture. One fixture unit represents a flow of about 7½ gallons per minute of waste or sewage. Rather than running a separate pipe from each fixture to the sewer, individual branch-pipes from each fixture are connected to horizontal branches leading to vertical stacks (soil or waste) which in turn connect to the horizontal building drain at the lowest level. As the drainage piping in the building is so connected to serve increasing number of fixtures, the size must be increased accordingly.

From fixture branches to soil and waste stacks, to building sewer, to house sewer, the drainage system is the same whether it connects to a public or private disposal system. However, while the size of a public sewer is the responsibility of the community, the size and type of a private disposal system is based on the soil and site conditions and on the probable quantities of waste.

If the building sewer is made of clay pipe, roots of trees and shrubs may penetrate the joints of the line and obstruct the flow; the joints of the other approved materials are less rigid and less liable to such penetration.

In some cases, there is a possibility that sewage could flow backwards into the building drain or even into the building; in such cases, a backflow preventer should be installed.

Dishwashers and clotheswashers should not drain directly into the waste system, but through an indirect waste, having an air gap twice the diameter of the indirect waste pipe. The indirect waste receptor should be large enough to accept surges of water.

Venting System

Since the organic waste in the drainage system is subject to decay, the drainage system must be provided with means of preventing any gases resulting from decomposition from passing through the plumbing fixtures into the building. The basic means used is the trap (Figure 4-16a), a U-shaped pipe which catches and holds from each dischage a certain quantity of water through which the gases cannot force their way. The effect of sewer gases on the human body is known, some being extremely harmful, and some being explosive.

Two types of trap are approved: The P-trap (for most fixtures), and a drum trap for bathtubs and showers. An S-trap or any form of mechanically-sealed trap are not approved. Traps are available in steel, cast iron, copper, brass, plastic, or glass, except that water closets and urinals generally have a trap built into the fixture and are, therefore, of vitreous china.

The water seal in the trap prevents the passage of the unpleasant and unhealthy sewer gases in the drainage system into the air of the room. The deeper the seal, the greater resistance to siphoning of the seal. However, since a deep seal might retard the flow of waste through the trap and cause the solids to deposit and foul the line, the Code requires a 2 inch minimum depth and a 4 inch maximum depth. If a trap serves a fixture like a floor drain which might not have water flowing frequently, and the water seal might evaporate, Codes require that either the drain be automatically primed to maintain the seal, or the use of a seal deeper than 4 inches, since no solid waste normally goes into the drain. Traps are normally located within 2 feet of each fixture, but certain fixtures can be connected and served by one trap under some circumstances.

If the vertical stack of the drainage system were closed at the top, a sudden and rapid discharge of water from a fixture could cause a variety of air currents which might empty the water from a trap either by propulsion or suction. To avoid this, stacks penetrate through the roof and are open at the top, and a separate venting system must be installed to supply sufficient fresh air to the drainage stacks and branches to balance air presures, dilute the gases, and permit their passage upward out of the building (see Figure 4-17). The trap must be vented close to its connection to the stack or branch; in effect, that portion of the stack above the fixture-connection is a part of the venting system.

Loop venting or circuit venting (Figure 4-18) simplifies construction since it protects the several traps adequately without requiring a separate vent stack for each fixture. Codes have limitations on the allowable distance from a trap to its vent.

In a building of more than one story a separate vent stack is normally required since waste moving downward through a stack which also serves as a vent for a lower fixture could empty the lower trap seal. Combination waste (not soil) vents are permitted under some circumstances, generally in residential bathrooms since drainage from a lavatory and the bathtub is unlikely to occur at the same time. A more recent development approved for high-rise buildings permits a single stack (serving as both drain and vent) since the design of the fittings alleviates the "piston" effect of waste moving downward.

Plumbing Fixtures

Since plumbing fixtures are a primary terminal of both the water supply and drainage systems, they determine the quantity of water required and the capacity of the drainage system. The number and type of fixtures in any building intended for occupancy by humans must include at least one water closet and one wash basin. Above that minimum level, the Code requires one fixture for a certain number of occupants, depending on the type of occupancy, with a Code-assumed ration of male/female for certain occupancies. It is conceivable, therefore, that change-in-use of an existing building might well require the addition of additional facilities. This is generally the case if a change to residential occupancy is involved, since the Code does require that each dwelling unit be provided with a separate bathroom and kitchen.

Types of plumbing fixtures include: water closets, urinals, lavatories (wash basins), bath tubs, showers, kitchen sinks, and service sinks. The advantages of a well-designed plumbing system would be voided if the fixtures connected to it absorbed waste material or contained roughened areas or projections that might catch and hold foul matter. Every type of fixture must be made of hard impervious materials with smooth surfaces. Normally they must be set free of enclosures to allow circulation of air and access for cleaning use. However, lavatories and sinks, if properly installed, can be built into a counter top.

The design of the water inlet into the fixture and its over-flow connection must be designed so as to prevent backflow of soiled water into the water supply (Figure 4-19), thereby avoiding cross-connection between potable and non-potable water. For example, a faucet with a water-supply opening 1/2" in diameter must be 1" above the flood level rim of the fixture it serves. Similarly, any fitting, such as a hose bibb, whose use might provide an opportunity for backflow of contaminated water, must contain backflow prevention devices.

All of the plumbing fixtures required for a dwelling unit must be located within the dwelling unit. The bathroom should be at least 30 square feet, and afford privacy to the users. Also, access to a common bathroom should not be only through a bedroom. Water closets, urinals and bathing facilities in other occupancies must be screened for privacy.

ENERGY

Electricity

GENERAL

The use of electrical energy for heating, cooling, ventilating, lighting, and for operating equipment, appliances, and tools has increased rapidly in the last 30 years.

The 1975 "Recommended Housing Maintenance and Occupancy Ordinance," developed by the American Public Health Association, allows a dwelling that is located more than 300 feet from the nearest electrical source to be without this service; however, there are very few dwellings left in the populated areas of this country that do not have, within 300 feet, the lines of the local electric utility.

Although electricity is a valuable servant, it can also be a severe safety hazard. Among the most common faults in providing electrical service is furnishing inadequate outlets. This results in overloading of the lines, causing possible overheating of wires and fixtures and subsequent fire hazards. Improperly installed facilities and outlets furnish a fire hazard as well as a safety hazard, particularly to small children.

When inadequate outlets are provided, there is a tendency, particularly among the poorly educated, to connect many high-wattage items such as toasters, irons, television sets, and other similar items to a single outlet. Kitchen, living rooms, and rooming units are most likely to contain several electrical appliances in addition to the lighting fixtures. This is not necessarily true in toilet rooms, laundry rooms, furnace rooms, and public hallways. It is very important, therefore, that rooms most likely to have a large number of appliances be required to have an adequate number of outlets in order to prevent overloading of circuits and installation of amateurish and possibly hazardous extension wiring.

There are two basic Codes concerned with residential wiring that are of importance to the housing inspector.

The first is the local Electrical Code. The purpose of this Code is to safeguard persons and buildings and their contents from hazards arising from the use of electricity for light, heat, and power. The Electrical Code contains basic minimum provisions considered necessary for safety. Compliance with this code and proper maintenance will result in an installation essentially free from hazard but not necessarily efficient, convenient, or adequate for good service or future expansion. The majority of local electrical codes are modeled after the National Electrical Code, published by the National Fire Prevention Association.

Just because an electrical installation was safe and adequate under the provisions of the Electrical Code at the time of installation does not indicate that the system is safe and adequate for use today. Hazards often occur because of overloading of wiring systems by methods or usage not in conformity with the Code. This occurs because initial wiring did not provide for increases in the use of electricity. For this reason it is recommended that the initial installation be adequate and that reasonable provisions for system changes be made as may be required for future increase in the use of electricity.

The other code that contains electrical provisions is the local Housing Code. It establishes minimum standards for artificial and natural lighting and ventilation, specifies the minimum number of electrical outlets and lighting fixtures per room, and prohibits temporary wiring except under certain circumstances. In addition, the Housing Code usually requires that all of the electrical system be installed and maintained in a safe condition so as to prevent fire or electrical shock.

SERVICE

Providing electrical energy to the building is the last stage in one power flow (see Figure 4-20), and the beginning of another. In order for electric current to flow, it must travel from a higher to a lower potential voltage. In an electrical system the hot wires (black or red) are at a higher potential voltage than the neutral or ground wires (white or green). Therefore, current will flow between the hot wires and the neutral or ground wires.

The voltage is a measure of the force at which electricity is delivered. It is similar to pressure in a water supply system.

Current is measured in amperes and is the quantity of flow of electricity. It is similar to measuring water in gallons per minute.

A watt is equal to volts times amperes. It is a measure of how much power is flowing. Electricity is sold in quantities of watt-hours.

The earth, by virtue of moisture contained within the soil, serves as a very effective conductor. Therefore, in power transmission, instead of having both the hot and neutral wires carried by the transmission poles, one lead of the generator is connected to the ground, which serves as a conductor (see Figure 4-20). Only hot wires are carried by the transmission towers. At the house, or point where the electricity is to be used, the circuit is completed by another connector to the ground.

The electric power utility provides a ground somewhere in its local distribution system; therefore, there is a ground wire in addition to the hot wires within the service drop. In Figure 4-20 this ground can be seen at the power pole that contains the stepdown transformer.

In addition to the ground connection provided by the electric utility, every building is required to have an independent ground, called a "system ground." The system ground provides for limiting the voltage upon the circuit which might otherwise occur through exposure to lightning, or for limiting the maximum potential to ground due to normal voltage. Therefore, the system ground's main purpose is to protect the electrical system itself and to offer limited protection to the user. The system ground serves the same purpose as the power company's ground; however, being closer to the building, it has a lower resistance. The system ground should be a continuous conductor of low resistance and of sufficient size to conduct current safely from lightning and overloads.

The "equipment ground," which we will discuss later in this chapter, protects users from potential harm during the use of certain electrical equipment.

ELECTRIC SERVICE ENTRANCE

The "Entrance Head" (see Figure 4-21) should be attached to the building at least 10 feet above ground, to prevent accidental contact by people. The service conductors should clear all roofs by at least 8 feet and residential driveways by 12 feet. For public streets, alleys, roads, and driveways on other than residential property the clearance must be 18 feet. The wires or conductors should be of sufficient size to carry the load and not smaller than No. 8 copper or equivalent.

For connecting wire from the entrance head to the service drop wires, the National Electrical Code requires that the service entrance conductors be installed either (1) below the level of the service head, or (2) below the termination of the service-entrance cable sheath. Drip loops must be formed on individual conductors (Figure 4-22). This will prevent water from entering the electric service system.

The wires that form "entrance cable" should extend 36 inches from the entrance head, to provide a sufficient length to connect service drop wires with insulators to the building (see Figure 4-22).

The entrance cable may be a special type of armored outdoor type of wire or it may be enclosed in a conduit. The electric power meter may be located either within or outside the building. In either instance, the meter must be located before the main power disconnect.

Figure 4-23 shows use of a conduit in a service entrance. The conduit is anchored to the building with metal straps spaced every four feet. The cable is run through the conduit and through a hole drilled through the building. The cable is then connected to the service panel, which should be located within one foot of where the cable enters the building.

The ground wire need not be insulated. This ground wire may be either solid or stranded copper, or a material with an equivalent resistance.

If the service is run underground, the cables must be protected from moisture and physical damage. The opening in the building foundation where the underground service enters the building must be moisture proof. Allowable materials for this type of service entrance are designated in the Code.

The service switch, part of the electrical service panel, is a main switch that will disconnect the entire electrical system at one time. The main fuses or circuit breakers are usually located within the service panel box. The branch circuit breakers may also be located within this box (Figure 4-24).

According to the Code, the service switch must be "externally operable." This condition is fulfilled if the switch can be operated without the operator's being exposed to electrically active parts. Older switches use external handles, but most of today's service switches do not have hinged switch blades. Instead, the main fuse is mounted on a small insulated block that can be pulled out of the switch. When this block is removed, the circuit is broken just as if the blades had been operated with a handle.

The neutral terminal or wire of a grounded circuit must never be interrupted by a fuse or circuit breaker. In some installations the service switch is a "solid neutral" switch. This means that the neutral wire in the switch is not broken by the switch or a fuse.

When circuit breakers instead of fuses are used in homes, the use of main circuit breakers may or may not be required. If it takes not more than six movments of the hand to open all the branch-circuit breakers, no main breaker or switch or fuse will be required ahead of the branch-circuit breakers. Thus, a house with seven or more branch circuits requires a separate disconnect means or a main circuit breaker ahead of the branch circuit breakers (see Figure 4-24).

The system ground consists of grounding the neutral incoming wire as well as the neutral wire of the branch circuits. The equipment ground consists of grounding the metal parts of the service entrance, such as the service switch, as well as the service entrance conduit, armor, or cable.

In the past, the usual ground connection was to a water pipe of the city water system. The connection should be made to the street side of the cold water meter as shown in Figure 4-25, or if the water meter is located near the street curb, the ground connection should be made to the cold water pipe as close as possible to where it enters the building. If the water piping is used for grounding, a jumper should be provided at the water meter to allow replacement of the meter without interrupting the ground.

However, due to the use of plastic piping for water service installation and maintenance or repair, a positive ground using a grounding electrode is recommended by the code. The most common ground is a pipe or rod that is driven into the ground a distance of at least 8 feet. If the pipe is made of steel or iron, it must be 3/4 inch in diameter and galvanized. A copper ground pipe of 1/2 inch diameter is sufficient.

The Code requires that a ground rod be entirely independent of and kept at least 6 feet from any other ground of the type used for radio, telephone, or lightning rods.

Often an amateur mechanic, in the process of doing repair, will disconnect the house ground. Therefore, the inspector should always check the house ground to see if it is properly connected.

Figure 4-26 shows a typical grounding scheme at the service panel of a residence. In this figure, only the grounded neutral wires are shown. The neutral strap is an uninsulated metal strip that is riveted directly to the service box. The ground wires from the service entrance, branch circuits, and house ground are joined by this strip.

OVERCURRENT PROTECTION

The amperage (current flow) in any wire is limited to the maximum permitted by using an overcurrent device of a specific size as specified by the Code. The overcurrent device must be rated at equal or lower capacity than the wire of the circuit it protects. Two types of overcurrent devices are in common use, circuit breakers and fuses, both rated in amperes.

A circuit breaker (see Figure 4-27) looks something like an ordinary electric light switch. There is a handle that may be used to turn power on or off. Inside is a simple mechanism that, in case of a circuit overload, trips the switch and breaks the circuit. The circuit breaker may be reset by simply flipping the switch. A circuit breaker is capable of taking harmless short-period overloads (such as the heavy initial current required in the starting of a motor for a washing machine or air conditioner) without tripping but protects against prolonged overloads. After the cause of trouble has been located and corrected, the power is easily restored by flipping the circuit breaker switch (circuit breakers are modern substitutes for fuses).

Fuse-type panel boxes are generally found in older homes. They are equally as safe and adequate as a circuit breaker of equivalent capacity, provided fuses of the proper size are used, and that substitutes (such as a penny) are not used.

A fuse, like a circuit breaker, is designed to protect a circuit against the dangers of overloading and short circuits and does this in two ways:

1. When a fuse is blown by a short circuit the metal strip is instantly heated to an extremely high temperature, and this heat causes it to vaporize. A fuse blown by a short circuit may be easily recognized because the window of the fuse usually becomes discolored.

2. In a fuse blown by overload the metal strip is melted at its weakest point, and this breaks the flow of current to the load. In this case the window of the fuse remains clear.

Sometimes, although a fuse has not been blown, the bottom of the fuse may be severely discolored and pitted. This indicates a loose connection due to the fuse not being screwed in properly.

There are several types of fuses. All ordinary plug fuses, shown in Figure 4-28a, have the same diameter and physical appearance regardless of their current capacity. Thus, if a circuit designed for a 15-ampere fuse is over-loaded so that the 15-ampere fuse blows out, nothing may prevent replacing the fuse with a 20- or 30-ampere fuse; if an overload develops, more current than the No. 14 wire (with capacity of 15 amperes) is safely capable of carrying could pass through the circuit. The result would be over-heating of the wire and a potential fire.

Type S fuses, non-tamperable fuses, have different lengths and diameter threads for each different amperage capacity. An adapter is first inserted into the ordinary fuse holder, which adapts the fuse holder for only one capacity fuse. Once the adapter is inserted it cannot be removed (Figure 4-28b).

Figure 4-28c shows two different types of cartridge fuses. A cartridge fuse protects an electric circuit in the same manner as an ordinary plug fuse. Cartridge fuses are often used as main fuses.

SIZE OF SERVICE

Many home owners have failed to repair or improve their wiring to keep it safe and up to date. The National Electrical Code recommends that individual residences be provided with a minimum of 100-ampere, three-wire service. This type service is sufficient in a one-family house or dwelling unit to provide safe and adequate electric supply for the lighting, refrigerator, dryer and a range, plus other appliances, requiring a total of up to 23,000 watts altogether.

Some homes have a 60-ampere, three wire service, providing 13,800 watts. It is recommended that these homes be rewired for at least the minimum of 100 amperes recommended in the National Code since they are safely capable of supplying current only for lighting and small appliances. Since a range may need at least 8,000 watts, a clothes dryer 4,500, and a waterheater 2,500, this service cannot handle additional major appliances.

Other homes today have only a 30-ampere, 115-volt, two-wire service (3,450 watts). This system can safely handle only a limited amount of lighting, a few minor appliances, and no major appliances. Therefore, this size service is substandard in terms of modern houshold needs for electricity, and should be replaced together with the appropriate service panels. Furthermore, it constitutes a fire hazard and a threat to the safety of the home and the occupants.

DISTRIBUTION

One of the wires in every installation is grounded. This neutral wire is always white. The hot wires are usually black or red or some other color, but never white.

The potential difference or voltage between the hot wires and the ground or neutral of a normal residential electrical system is 115 volts. Thus, where we have a two-wire installation (one hot and one neutral) only 115-volt power is available.

When three wires are installed (two hot and one neutral) either 115- or 230-volt power is available. In a three-wire system the voltage between the neutral and either of the hot wires is 115; between the two hot wires it is 230 volts. The major advantage of a three-wire system is that it permits the operation of heavy electrical equipment such as laundry dryers, cooking ranges, and air conditioners, the majority of which require 230-volt circuits. In addition, the three-wire system can be split at the service panel into two 115-volt systems to supply power for small appliances and electric lights. The result is a doubling of the number of circuits, and possibly a corresponding increase in the number of branch circuits, with a reduction of the probability of fire caused by overloading electrical circuits.

Electric power flows over wire. It flows with relative ease (little resistance) in some materials such as copper, and with a substantial amount of resistance in iron. If iron wire were used, it would have to be 10 times as large as copper wire. Wire sizes are indicated by a number. Number 14 is most commonly used in residential branch circuits in copper. Number 14 is the smallest permitted by the Code for use in a branch circuit with a 15-ampere capacity. Numbers 16, 18, and 20 are progressively smaller than Number 14 and are usually used for extension wires. As the number of the wire becomes smaller, the size and current capacity of the wire increases. Number 1 is the heaviest wire usually used in ordinary household wiring.

Wire of correct size must be used for two reasons: current capacity, and voltage drop. When current flows through a wire it creates heat. The greater the amount of flow, the greater the amount of heat generated. (Doubling the amperes without changing the wire size increases the amount of heat by four times.) The heat is electric energy that has been converted into heat energy by the resistance of the wire; the heat created by the coils in a toaster is an example. This heat developed in an electrical conductor is wasted, and thus the electric energy used to generate it is wasted. If the amount of heat generated by the flow of current through the wire becomes excessive, a fire may result. Therefore, the Code sets the maximum permissible current that may flow through a certain type and size wire as shown in Table 4-2.

In addition to heat generation there will be a reduction in voltage as a result of resistance to more current flowing through a wire than it is capable of carrying. Certain appliances, such as induction-type electric motors, may be damaged if operated at too low a voltage.

All wires must be marked to indicate the maximum working voltage, the proper type letter or letters for the type wire specified in the Code, the manufacturer's name or trademark, and the AWG size or circular-mil area.

There are a variety of wire types which can be used for a wide range of temperature and moisture conditions, depending on the insulations used. The latest edition of the National Electrical Code should be consulted to determine the proper wire for specific conditions, depending on the insulations used.

Nonmetallic sheathed cable consists of insulated wires wrapped in a paper layer, followed by another spiral layer of paper, and enclosed in a fabric braid, which is treated with moisture-resistant and fire-resistant compounds. Figure 4-29 shows this type of cable, which often is marketed under the "Romex" name. This type of cable can be used only indoors and in permanently dry locations.

Armored cable is commonly known by the BX or Flexsteel trade names. Wires are wrapped in a tough paper and covered with a strong sprial flexible steel armor. This type of cable is shown in Figure 4-30 and may be used only in permanently dry indoor locations. Armored cable must be supported by a strap or staple every 6 feet and within 24 inches of every switch or junction box, except for concealed runs in old work where it is impossible to mount straps.

Cables are also available with other outer coatings of metals such as copper, bronze, and aluminum for use in a variety of conditions.

METHODS OF INSTALLATION

Two types of installation are found only in older buildings and no longer are permitted by the Code for new construction for most building types; however, they can be extended in existing buildings by approval of the electrical inspector.

Open wiring is a wiring method using knobs, non-metallic tubes, cleats, and flexible tubing for the protection and support of conductors in or on buildings and not concealed by the structure. The term "open wiring" does not necessarily mean exposed, bare wiring. In dry locations when they are not exposed to severe physical damage, conductors may be separately encased in flexible tubing. Tubing should be in continuous lengths not exceeding 15 feet and secured to the surface by straps not more than 4½ feet apart. They should be separated from other conductors by at least 2½ inches and should have a permanently maintained airspace between them and any and all pipes they cross (Figure 4-31a).

Concealed knob and tube wiring is a wiring method similar to open wiring but using knobs, tubes, and flexible nonmetallic tubing for the protection and support of insulated wires concealed in hollow spaces of walls and ceilings of buildings (Figure 4-31b).

Nonmetallic sheathed cable is permitted by the Code in dwellings and a few other occupancies. In still other occupancies, the conductors must be protected and installed using conduit, raceway, or busway. The Code establishes a limit on the size and number of conductors installed in conduits or other components, to allow the heat generated in the conductors to be dissipated.

All splices or other connections with conductors such as for receptacles, switches, fixtures, etc., must be made in outlet boxes (or other approved means).

CIRCUITS

An electric circuit in good repair carries electricity through two or three wires from the source of supply to an outlet back to the source.

A branch circuit is an electric circuit that supplies electric current to a limited number of electric outlets and fixtures. A residence generally has many branch circuits. Each is protected against short circuits and overloads by a 15- or 20-ampere fuse or circuit breaker.

The number of outlets per branch circuit varies from building to building. The Electrical Code requires enough general and lighting circuits that at least three watts of power will be available for each square foot of floor area in a house. A circuit wired with No. 14 wire and protected by a 15-ampere overcurrent protection device provides 15 x 115 or 1,725 watts; each circuit is enough for 1,725/3 or 575 square feet. Note that 575 is a maximum figure; if future use is considered, 500 or even 400 square feet per branch circuit should be used. In a residence, the number of outlets required is determined by the Code. For new construction, each length of wall in a room must have outlets at least every 12 feet.

It is a Housing Code requirement that every habitable room have two separate convenience outlets plus one wall-switch controlled electrical light fixture in bedrooms. It is also required that every habitable room used for food preparation shall have three wall-type duplex electric convenience outlets and one wall-switch controlled wall or ceiling-type electric light fixture. Bathrooms and laundry rooms must have at least one convenience outlet separate from the lighting fixture. No duplex outlet should serve more than two fixtures or appliances.

In other occupancies, the number of outlets per circuit is dependent on the rating of the circuit and the outlet, and the Electrical Code provides the watts/square feet to be used as the minimum. In no case can the load on a circuit exceed its capacity.

The general branch circuit will provide electric power for lighting, radio, television, and small portable appliances. However, the larger electric appliances usually found in the kitchen consume more power and must have their own special circuit.

Section 220-3b of the National Electrical Code requires two special circuits to serve only appliance outlets in kitchen, laundry, pantry, family-room, dining room, and breakfast room. Both circuits must be extended to the kitchen, the other rooms may be served by either one or both of these circuits. No lighting outlets may be connected to these circuits, and they must be wired with No. 12 wire and protected by a 20-ampere overcurrent device. Each circuit will have a capacity of 20 x 115 or 2,300 watts. (A toaster often requires over 1,600 watts.)

In addition to the special circuits above, in dwelling units it is customary to provide individual appliance circuits for each of the following appliances: range, water heater, automatic laundry, clothes dryer, garbage disposer, dishwasher, furnace, water pump.

FEEDER CIRCUITS

Rather than bringing each of the branch circuits back to the service panel, it is more economical and logical in buildings (other than normal one- and two-family dwellings) to supply the branch circuits from several feeder circuits, each sized for the combined load of its branch circuits. The feeder circuits then run from the protection at the service panel to the points where the branch circuits take off, each with its own overcurrent device.

Other Fuels

The other sources of energy (oil, gas, or coal) used in buildings currently provide energy primarily for heating and cooling, although in the past gas also was used for lighting.

OIL

Fuel oil is commercially available in five grades, numbered 1, 2, 4, 5, and 6. (Number 3 oil has been discontinued as a separate grade.) Number 1 oil is a transparent fluid similar to kerosene. It is more expensive and has a lower heading value per gallon than the other grades. As the classification number increases, the oil becomes darker and less fluid, and the heating value per gallon increases - from 136,000 Btu for Number 1 oil to 152,000 Btu for Number 6. Oils numbered 4, 5, and 6 are used only in industrial burners.

Oil tanks should be installed in accordance with Code requirements. Tanks are commonly located in the basement above the level of the burner. These tanks should not exceed 275-gallon capacity and should be 7 feet or more from any flame. They should be vented to the outside and should have an outside fillpipe connection. Two 275-gallon tanks are the maximum storage allowed in the basement. For larger installations, tanks must be outside the area of the house, preferably buried in the ground. Piping should be steel or brass pipe or brass or copper tubing (Figure 4-32).

GAS

Gas used for heating and cooking may be either natural gas or liquefied petroleum gas (LPG-either propane or butane)

Natural Gas

Natural gas has a heating value ranging from 960 to 1550 Btu per cubic foot depending on the location of the wells from which it is obtained. In some areas, bills for natural gas are rendered in terms of therms (100,000 Btu). The number of therms of gas used is obtained by multiplying the number of cubic feet consumed by the accepted heating value per cubic foot and then dividing this product by 100,000.

When gas is used as a fuel, gas pressure is maintained by a central gas plant, and no storage facilities are necessary on the customer's premises. The cost to the homeowner of installing gas pipe from the street mains to the burner depends upon local utility practice, and on the distance between the main and the burner.

The pressure of the gas is controlled by an automatic pressure regulator which reduces the gas pressure from the main supply lines to the exact amount needed in the burner.

LPG

Fuels of the butane and propane types are transported, sold and stored under pressure in the liquid state, but they are burned as a gas. They bring the convenience offered by gas to areas not served by pipe lines.

Two types of service are available to customers using this fuel. In one type, two small tanks are installed. Gas is drawn from one tank until it is empty. The connection to the burners is then switched, either manually or automatically, to the other tank. (In the latter case, a signal indicates the switch.) The customer notifies the dealer when a switch has been made, and the empty tank is replaced without any interruption of the service. The fuel supplied this way is usually sold by weight (Figure 4-33).

In the other type of service, a much larger tank is installed, and the liquid-fuel level is indicated by a float-operated guage. When the guage shows that the level is low, the customer notifies the dealer and the tank is refilled by pumping liquid fuel into it from a special tank truck. When liquefied petroleum gas is so supplied, the fuel is usually sold by the gallon, and the amount supplied is measured by a meter installed on the tank truck.

The heating value of these liquefied gases ranges from 21,000 to 22,000 Btu per pound and from 90,000 to 105,000 Btu per gallon. The heating value per gallon is considerably lower than that of fuel oil.

Burners for liquefied petroleum gases are similar to those used for burning other kinds of gas, the principal differences being:

- The pipe bringing the fuel to the burner is attached to a storage tank instead of to a gas main.
- The pressure regulator is usually required to operate against a much higher pressure in the pipe line than is the case with natural and manufactured gases.
- The orifice, which feeds the fuel into the air-mixing chamber of the burner, must be a smaller size.

Piping for gas should be steel or brass pipe, or brass or copper tubing.

COAL

Coal also is available in two types, anthracite and bituminous (most widely used).

Anthracite Coal

Anthracite coal (hard coal) produces little or no smoke in burning. It is well adapted for use in automatically-fired furnaces and boilers, and also in hand-fired heaters which are equipped with self-feeding supply chambers (magazines), because it does not soften and fuse together in the burning process. As a result, the coal flows readily by gravity action. Automatic ash removal is possible with anthracite coal because, in burning, large hard clinkers are not formed.

This fuel is sold in several sizes: broken, egg, stove, chestnut, pea, No. 1 buckwheat, and No. 4 buckwheat. The broken is the coarsest (3 1/4" to 4 3/8"), and the No. 4 buckwheat is the finest (3/64" to 3/32"). The smallest sizes are the least expensive, but special grates and fans to provide a forced draft are needed to burn them.

Anthracite coal produces an even heat. Its heating value is usually between 12,000 and 13,000 Btu per pound.

Bituminous Coal

Bituminous coal (soft coal) is sold in a wide variety of types, preparations and qualities. It is found in more areas of the country than anthracite and hence is less expensive in most regions because of lower transportation costs.

Some of the bituminous coals are nearly as hard as anthracite when handled or stored at outdoor or room temperatures, but they all soften and the lumps fuse together to a varying extent when heated in a fuel bed. They are, therefore, not well adapted for use in hand-fired furnaces or boilers having a magazine to feed the fuel to the fire by gravity. Most bituminous coals burn well in underfeed stokers.

Objectionable smoke is produced when this fuel is burned in ordinary hand-fired heaters unless special methods of firing are used.

Sizing practice in the bituminous coal industry has not been standardized as in the anthracite industry. Typical sizes of bituminous coal are run of mine (no separation of the different sizes), 5″ lump (all large lumps, each big enough to pass over a shaker screen having holdes five inches in diameter), 5″ x 2″ egg (passes through 5-inch holes and over 2-inch holes). 2″ x 1¼″ nut, 1¼″ x ¾″ stoker, and ¾″ screenings. Bituminous coal should be oil-treated for the elimination of dust.

The screenings contain all of the small particles and coal dust which are created by the mining process. They are considerably less expensive than any of the other sizes but are not used for home heating since special burning equipment is required. Some mines produce stoker coal for household use by removing all of the extremely small particles from the ¾″ screenings.

Some of the best grades of bituminous coals have higher heating values and lower ash contents than any of the anthracites. Heating values of bituminous coals range from less than 10,000 Btu per pound to nearly 15,000 Btu per pound.

Type of Flue	Required Area
Lined with fire-brick or Unlined	1/8 of fireplace opening area but not less than 100 square inches.
Square or Rectangle Lined	1/10 of fireplace opening area but not less than 64 square inches
Round Lined	1/12 of fireplace opening area but not less than 50 square inches

RECTANGULAR FLUE LININGS

STANDARD			MODULAR		
outside dimensions		*area (sq. in.)*	*outside dimensions*		*area (sq. in.)*
4½″	8½″	22	4″	8″	15
4½″	13″	36	4″	12″	20
8½″	8½″	51	4″	16″	27
8½″	13″	79	8″	8″	35
8½″	18″	108	8″	12″	57
13″	13″	125	8″	16″	74
13″	18″	168	12″	12″	87
18″	18″	232	12″	16″	120
20″	20″	279	16″	16″	162
20″	24″	338	16″	20″	208
24″	24″	420	20″	20″	262

ROUND FLUE LININGS

inside diam.	*wall thickness*	*area (sq. in.)*	*inside diam.*	*wall thickness*	*area (sq. in.)*
6″	⅝″	26	20″	1⅜″	298
8″	¾″	47	24″	1⅝″	433
10″	⅞″	74.5	27″	2″	551
12″	1″	108	30″	2⅛″	683
15″	1⅛″	171	33″	2¼″	829
18″	1¼″	240	36″	2½″	989.5

TABLE 4-1

MAXIMUM CAPACITY IN AMPERES

Size Wire (AWG)	# 14	# 12	# 10	# 8	# 6
Copper	15	20	30	40	55
Aluminum	—	15	25	30	40

TABLE 4-2

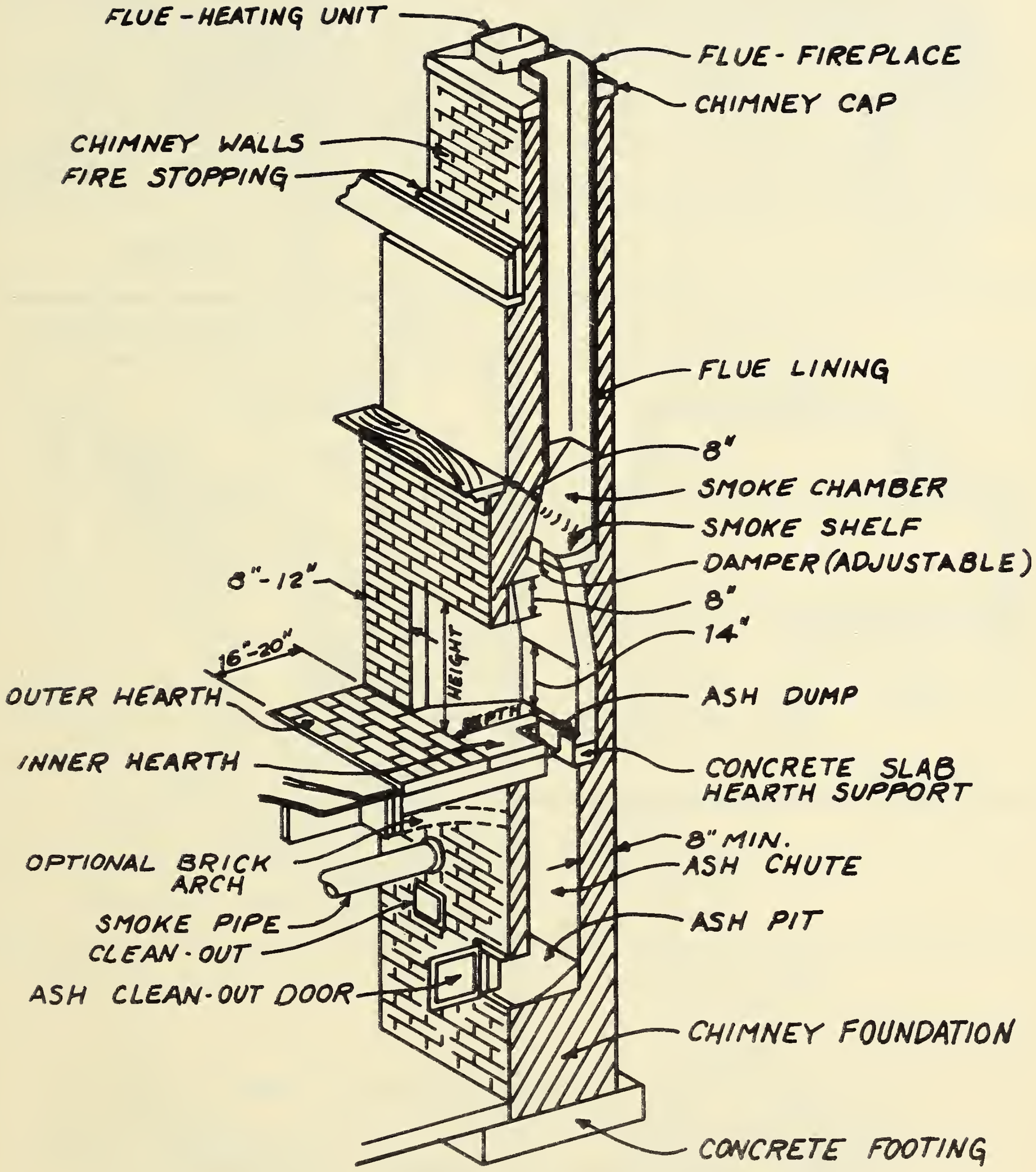

FLUE - HEATING UNIT
FLUE - FIREPLACE
CHIMNEY CAP
CHIMNEY WALLS
FIRE STOPPING
FLUE LINING
8"
SMOKE CHAMBER
SMOKE SHELF
DAMPER (ADJUSTABLE)
8"-12"
8"
14"
16"-20"
HEIGHT
OUTER HEARTH
ASH DUMP
DEPTH
INNER HEARTH
CONCRETE SLAB HEARTH SUPPORT
8" MIN.
OPTIONAL BRICK ARCH
ASH CHUTE
SMOKE PIPE
ASH PIT
CLEAN-OUT
ASH CLEAN-OUT DOOR
CHIMNEY FOUNDATION
CONCRETE FOOTING

Figure 4-1

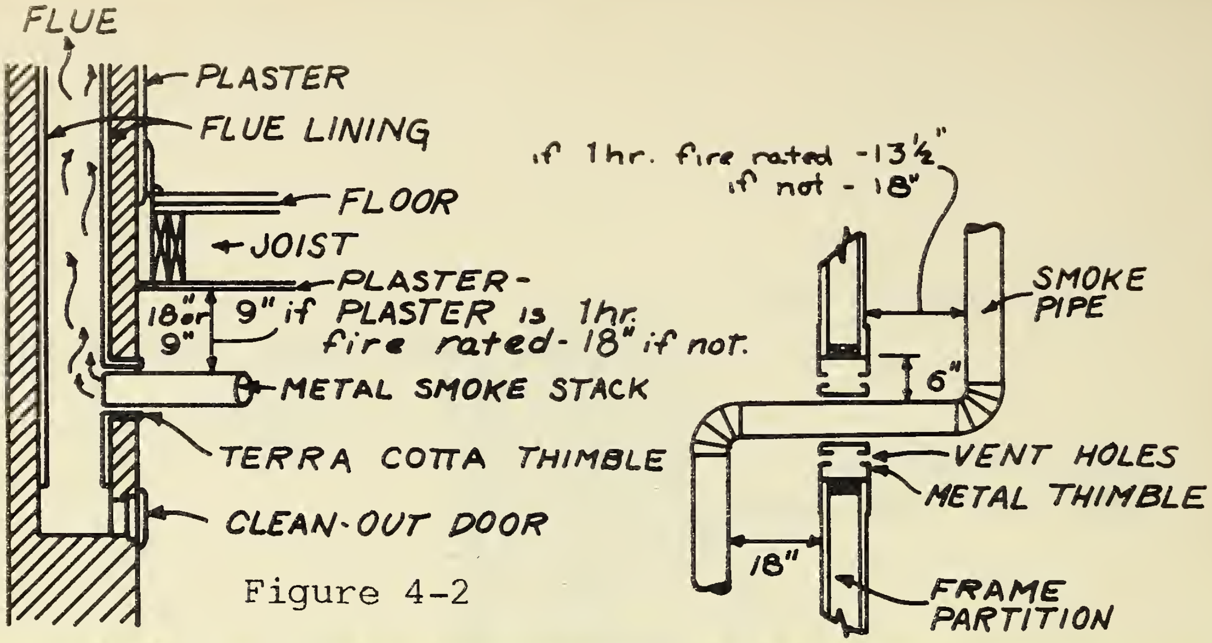


Figure 4-2

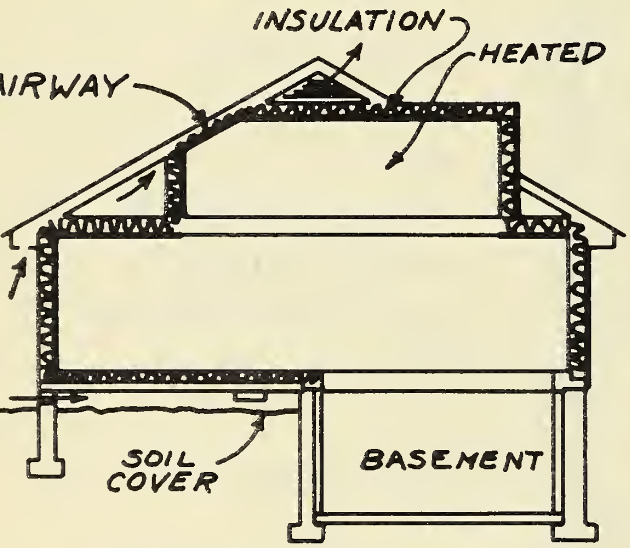


Figure 4-3

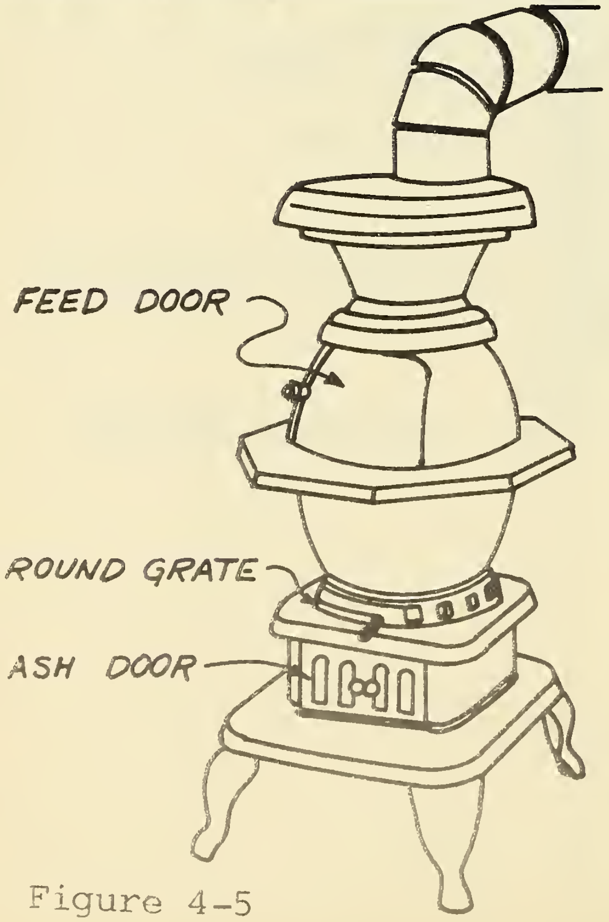


Figure 4-5

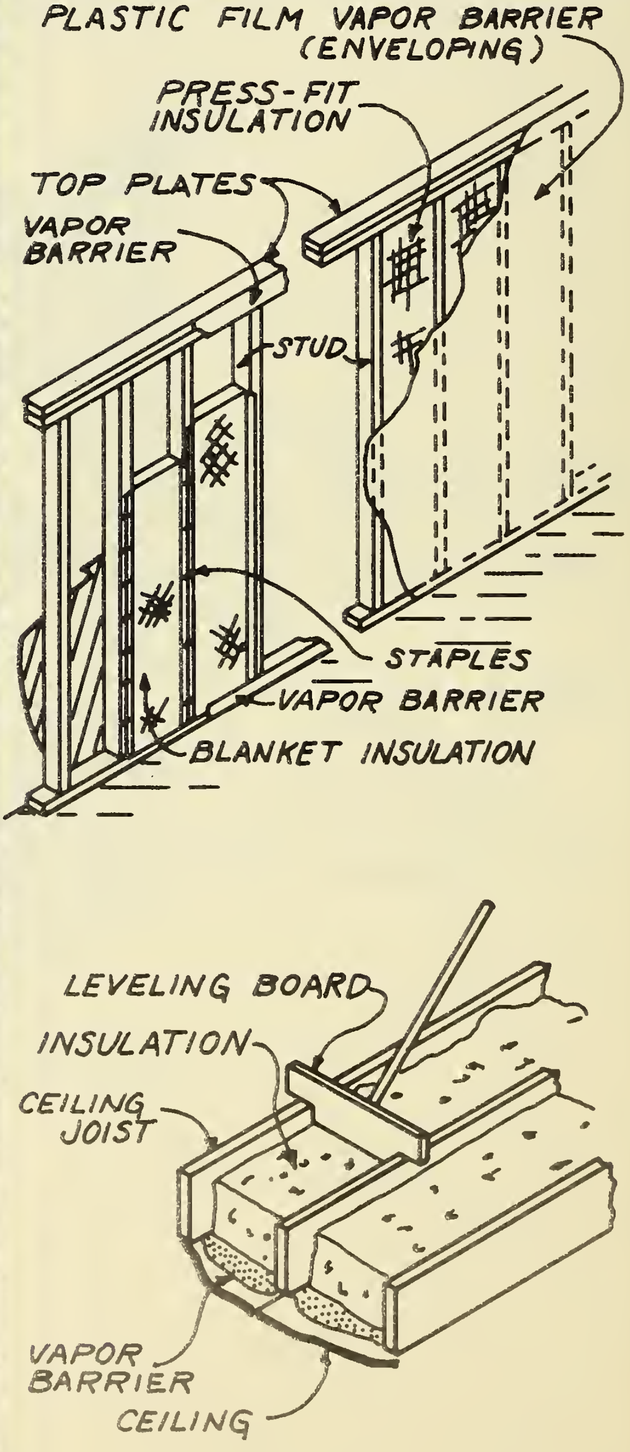


Figure 4-4

Figure 4-6

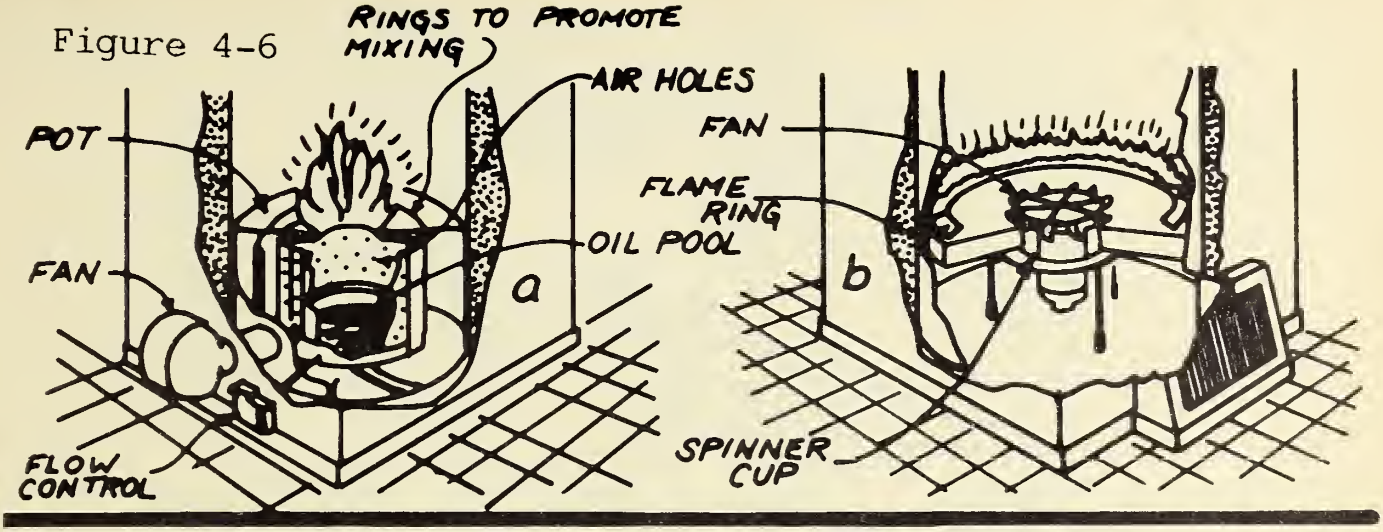


Figure 4-7

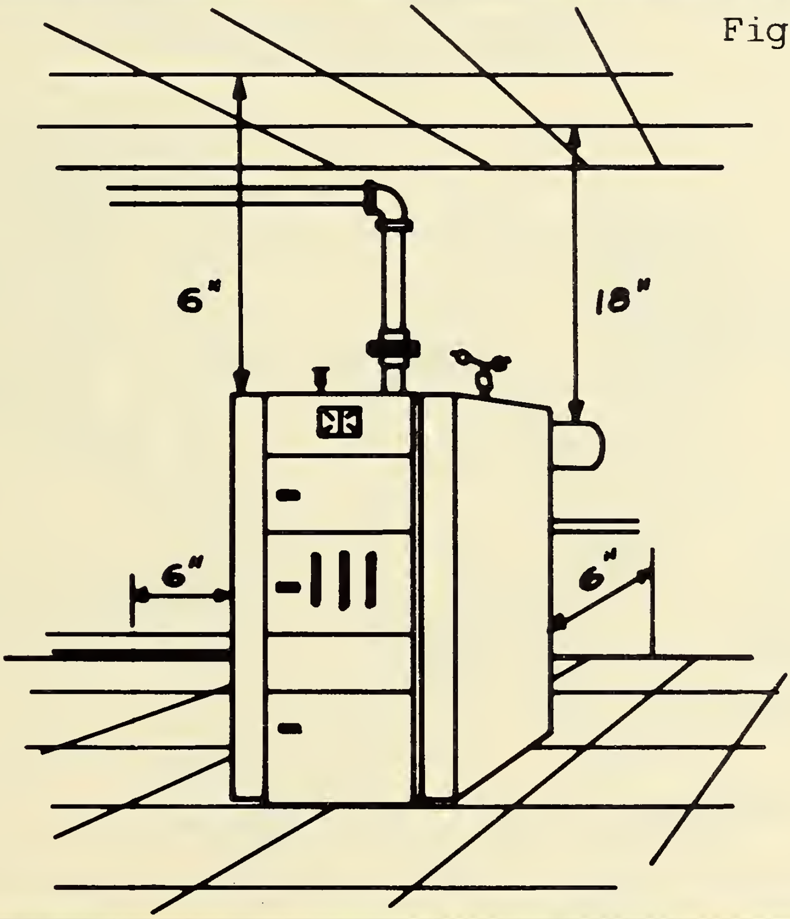
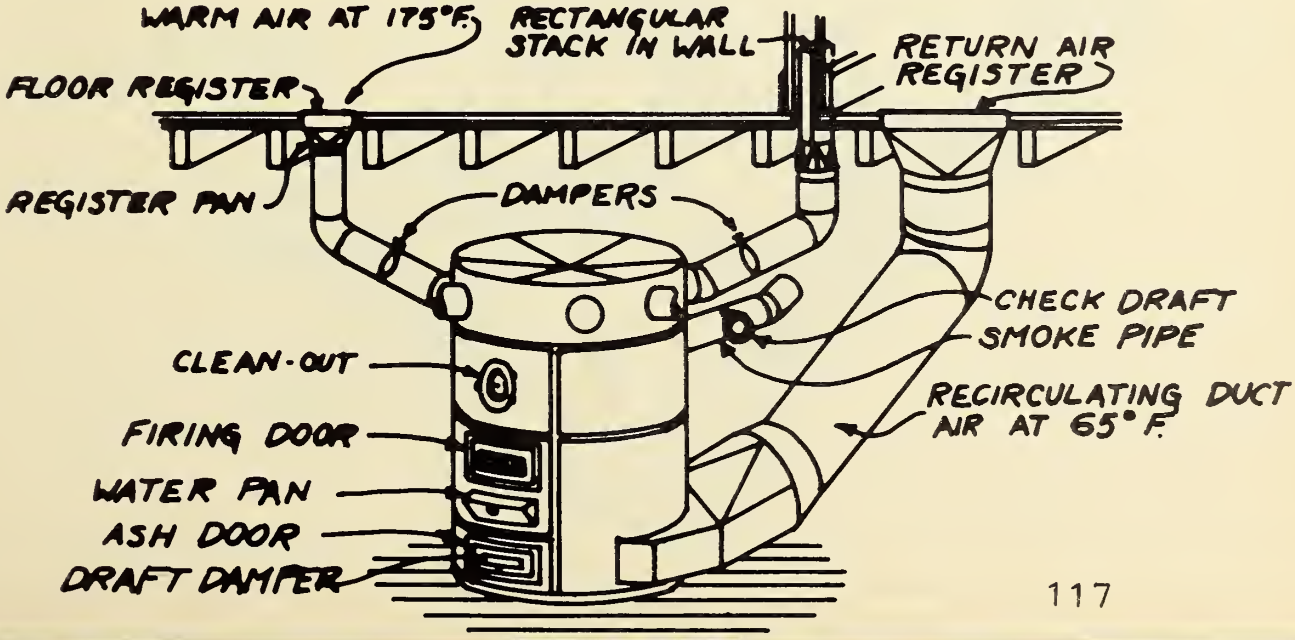


Figure 4-8



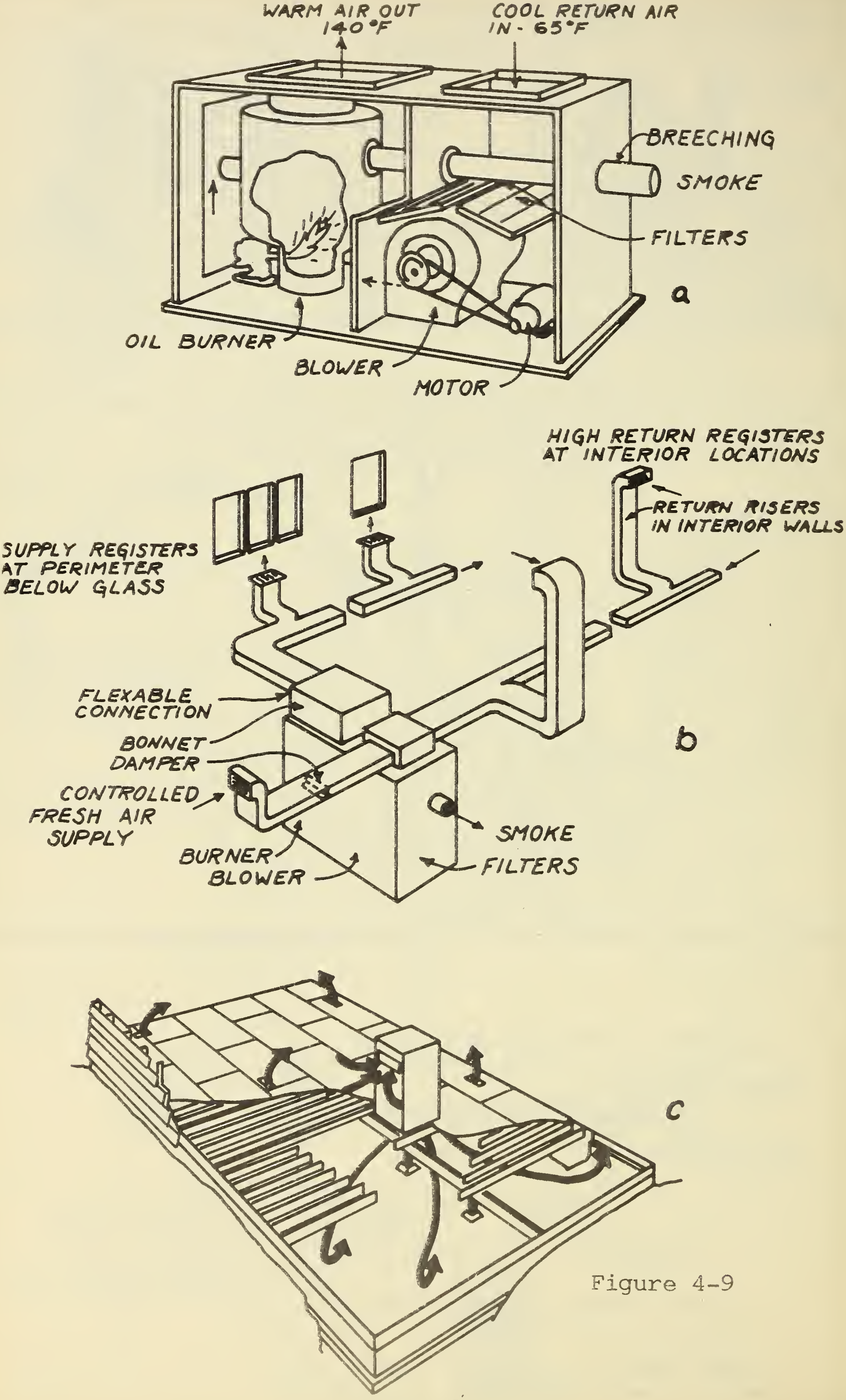

WARM AIR OUT 140°F
COOL RETURN AIR IN - 65°F
BREECHING
SMOKE
FILTERS
a
OIL BURNER
BLOWER
MOTOR
HIGH RETURN REGISTERS AT INTERIOR LOCATIONS
RETURN RISERS IN INTERIOR WALLS
SUPPLY REGISTERS AT PERIMETER BELOW GLASS
FLEXABLE CONNECTION
BONNET
DAMPER
CONTROLLED FRESH AIR SUPPLY
BURNER
BLOWER
SMOKE
FILTERS
b
c

Figure 4-9

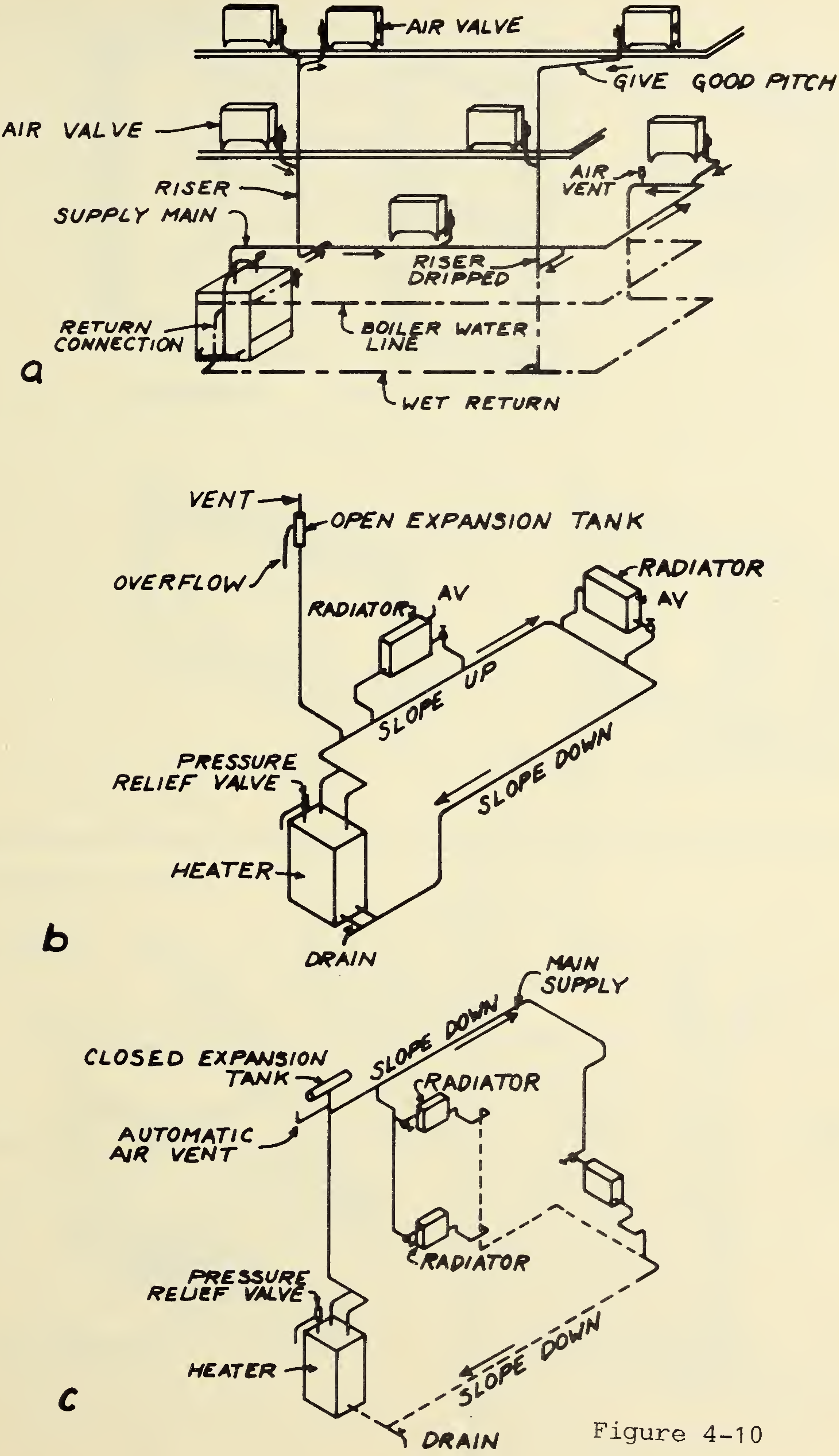

AIR VALVE
GIVE GOOD PITCH
AIR VALVE
AIR VENT
RISER
SUPPLY MAIN
RISER DRIPPED
RETURN CONNECTION
BOILER WATER LINE
a
WET RETURN
VENT
OPEN EXPANSION TANK
OVERFLOW
RADIATOR
AV
RADIATOR
AV
SLOPE UP
PRESSURE RELIEF VALVE
SLOPE DOWN
HEATER
b
DRAIN
MAIN SUPPLY
SLOPE DOWN
CLOSED EXPANSION TANK
RADIATOR
AUTOMATIC AIR VENT
RADIATOR
PRESSURE RELIEF VALVE
HEATER
SLOPE DOWN
c
DRAIN

Figure 4-10

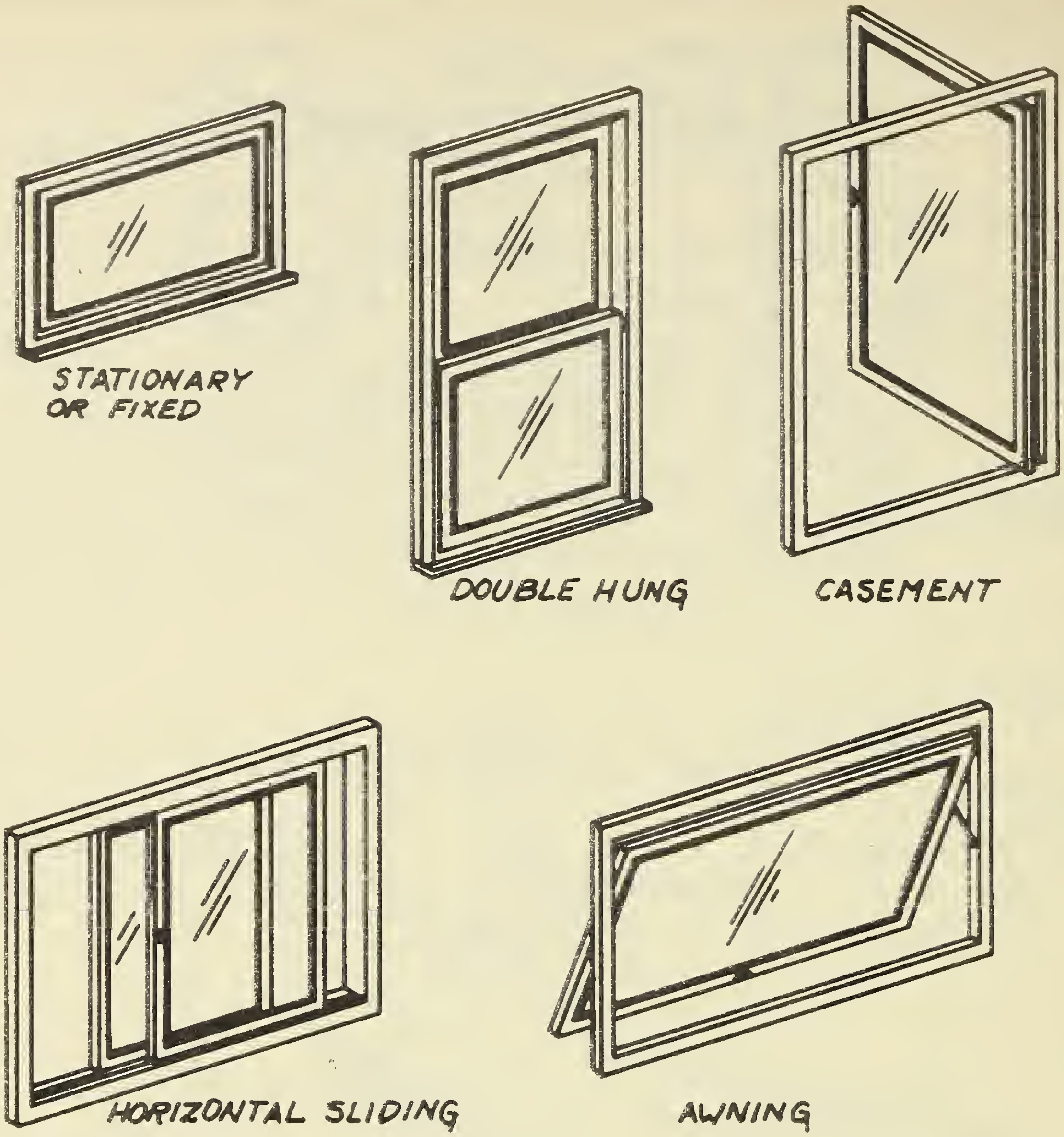


Figure 4-11

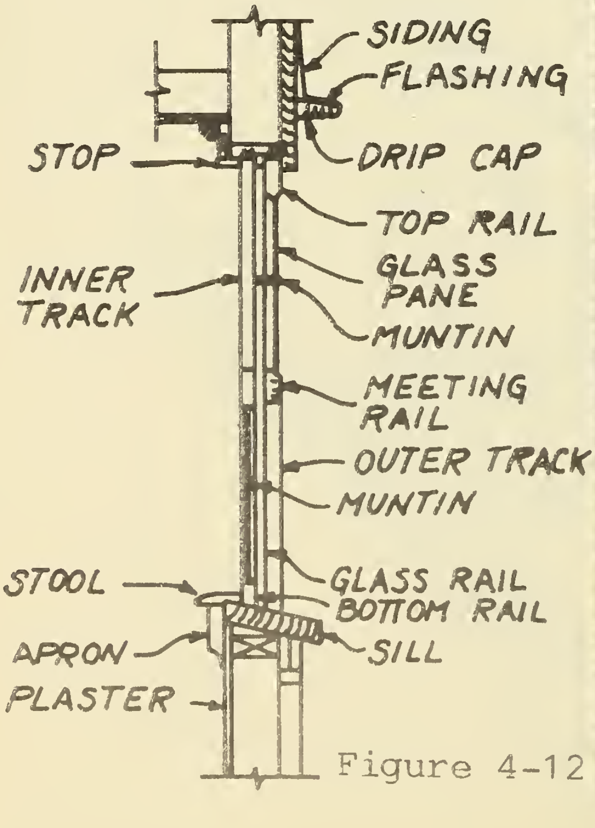


Figure 4-12

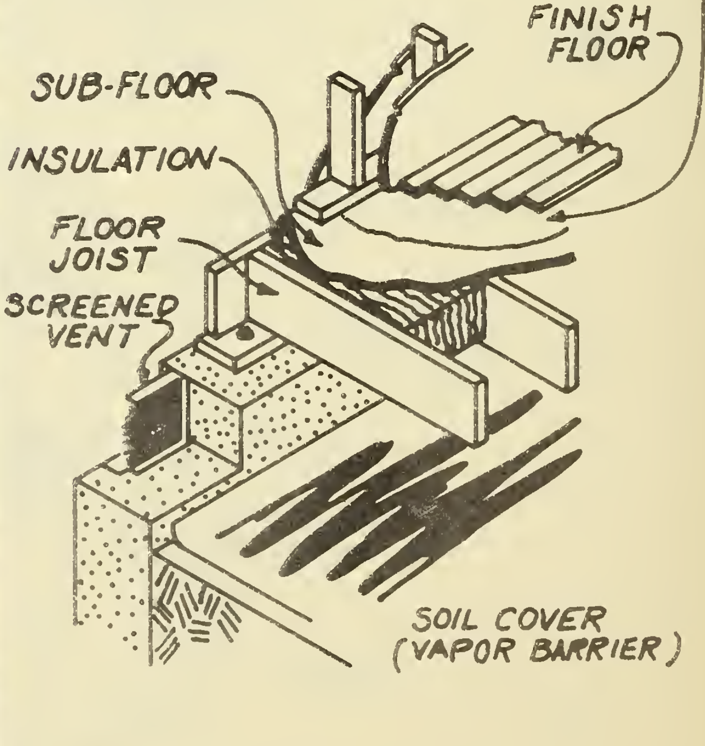
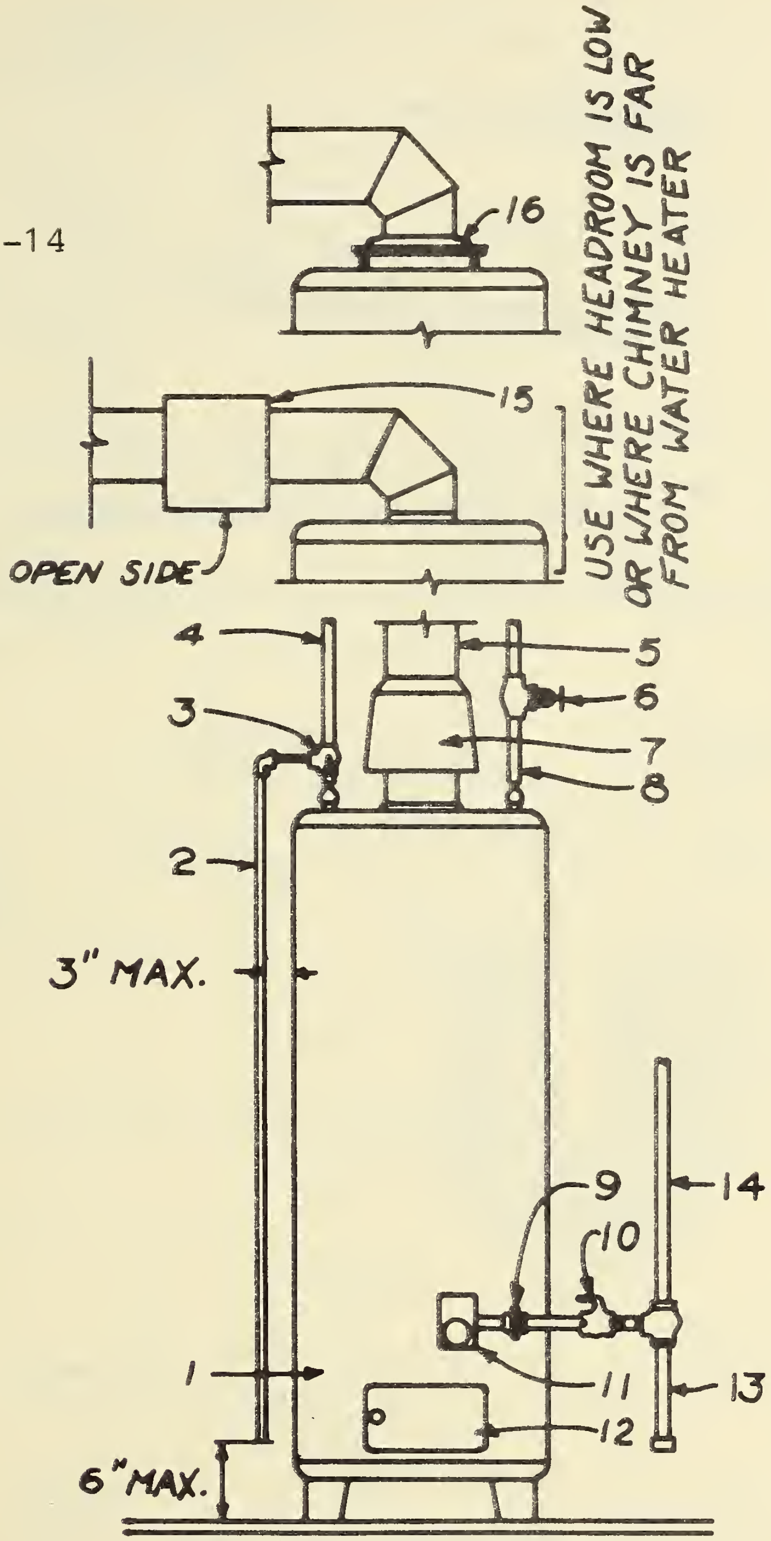


Figure 4-13

Figure 4-14



16
15
OPEN SIDE
USE WHERE HEADROOM IS LOW OR WHERE CHIMNEY IS FAR FROM WATER HEATER
4
3
5
6
7
8
2
3" MAX.
9
10
14
1
11
12
13
6" MAX.

1- HOT WATER HEATER
2- DRIP LEG (RELIEF VALVE)
3- COMBINATION TEMPERATURE AND PRESSURE RELIEF VALVE WITH TRY LEVER
4- HOT WATER LINE
5- FLUE PIPE - NOT LESS THAN 28 GAUGE GALVANIZED SHEET METAL
6- COLD WATER SHUT-OFF VALVE
7- DRAFT HOOD
8- COLD WATER LINE
9- UNION
10- SHUT-OFF VALVE (GROUND JOINT)
11- THERMOSTAT
12- PILOT LIGHT AND BURNER ACCESS DOOR
13- DRIP LEG (GAS LINE)
14- GAS SUPPLY LINE
15- HORIZONTAL DRAFT HOOD (SQUARE)
16- LOW PROFILE DRAFT HOOD

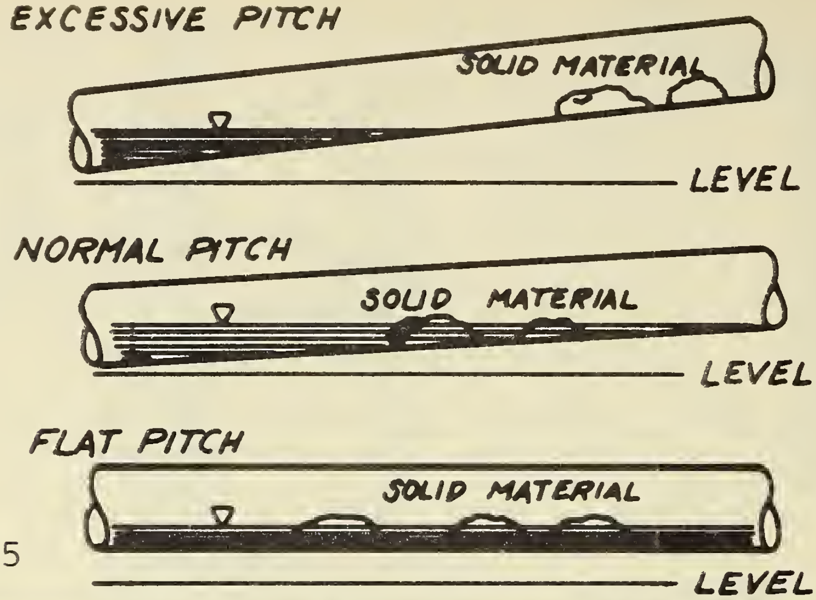
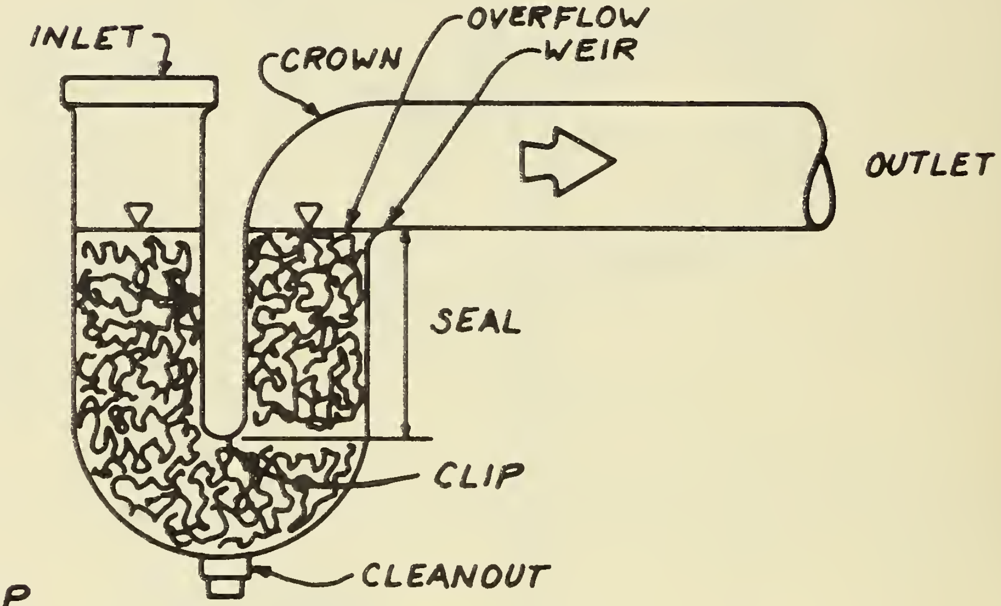
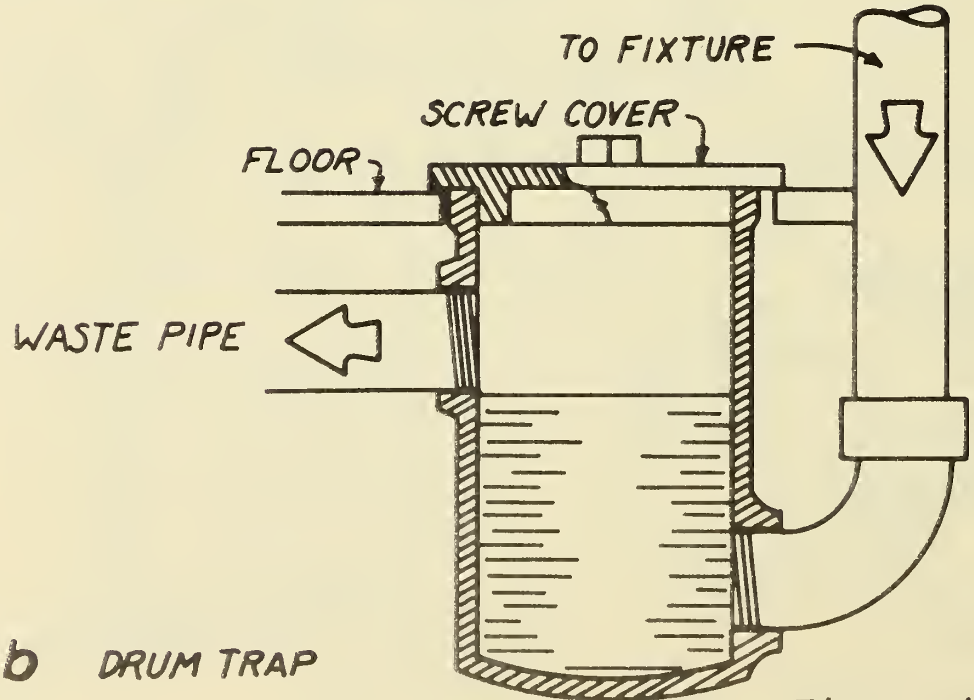


Figure 4-15



a P-TRAP



b DRUM TRAP

Figure 4-16

Figure 4-17

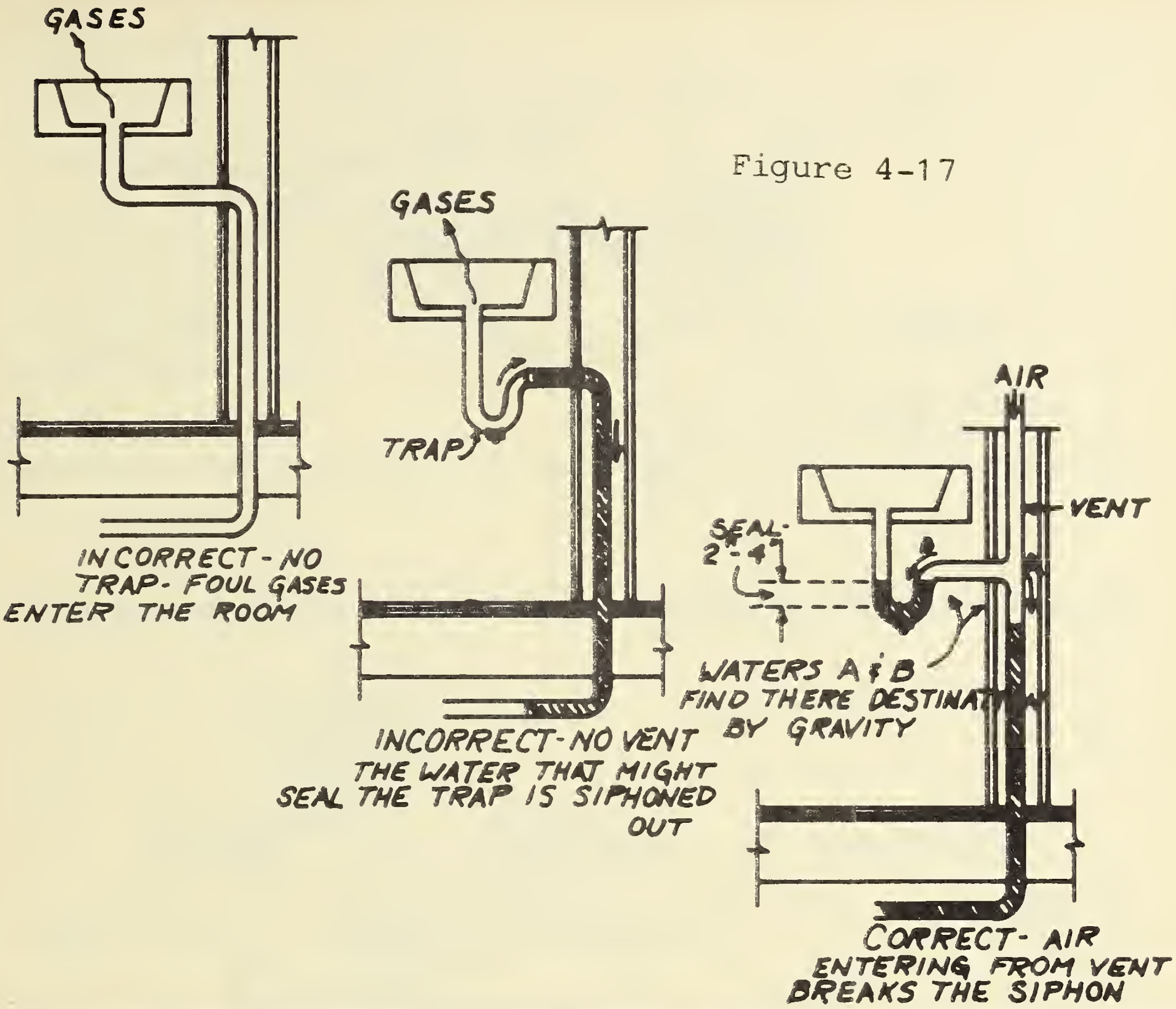
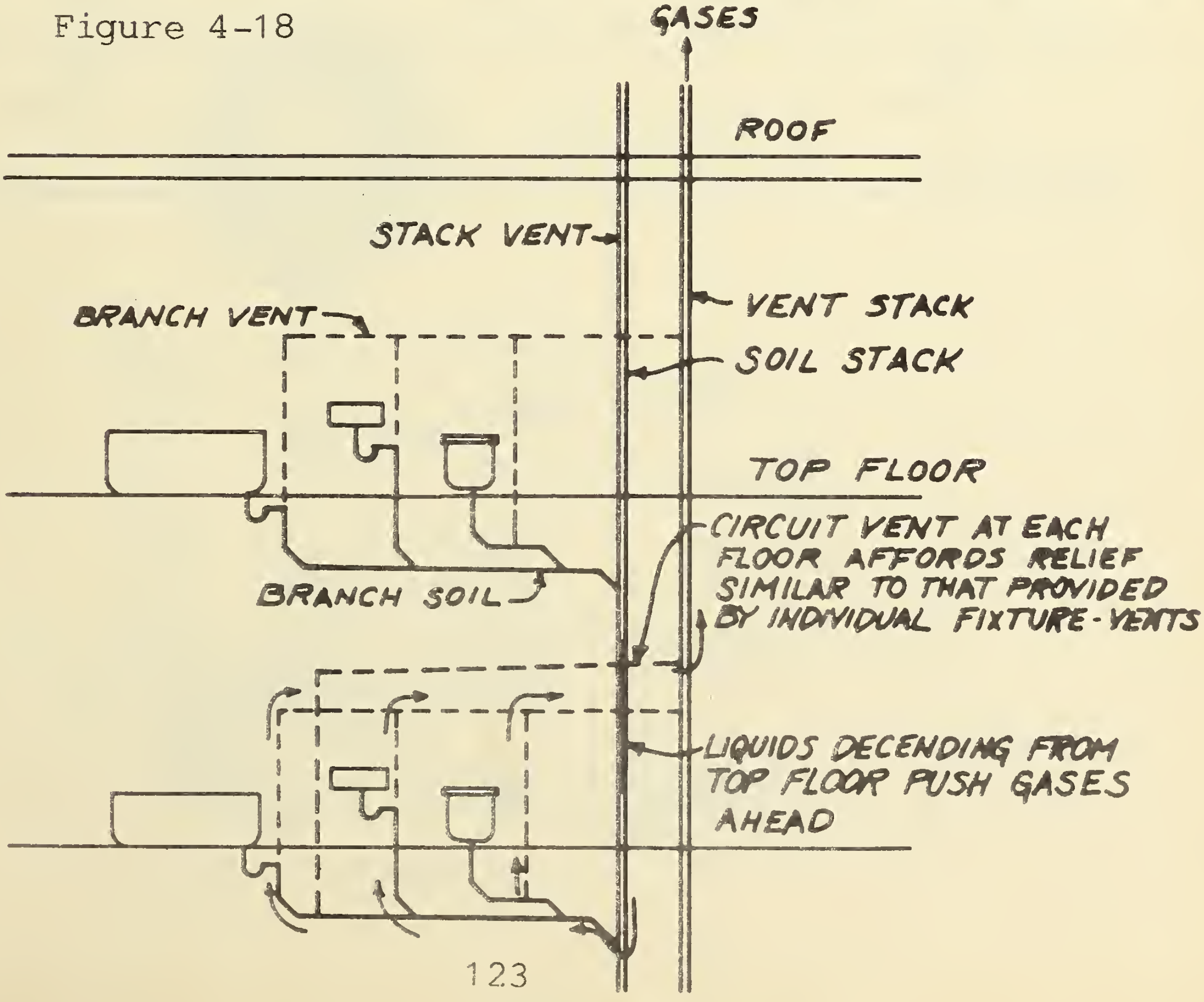

GASES
INCORRECT - NO TRAP - FOUL GASES ENTER THE ROOM
GASES
TRAP
INCORRECT - NO VENT THE WATER THAT MIGHT SEAL THE TRAP IS SIPHONED OUT
AIR
VENT
SEAL 2"-4"
WATERS A & B FIND THERE DESTINAT BY GRAVITY
CORRECT - AIR ENTERING FROM VENT BREAKS THE SIPHON

Figure 4-18


GASES
ROOF
STACK VENT
VENT STACK
BRANCH VENT
SOIL STACK
TOP FLOOR
CIRCUIT VENT AT EACH FLOOR AFFORDS RELIEF SIMILAR TO THAT PROVIDED BY INDIVIDUAL FIXTURE-VENTS
BRANCH SOIL
LIQUIDS DECENDING FROM TOP FLOOR PUSH GASES AHEAD

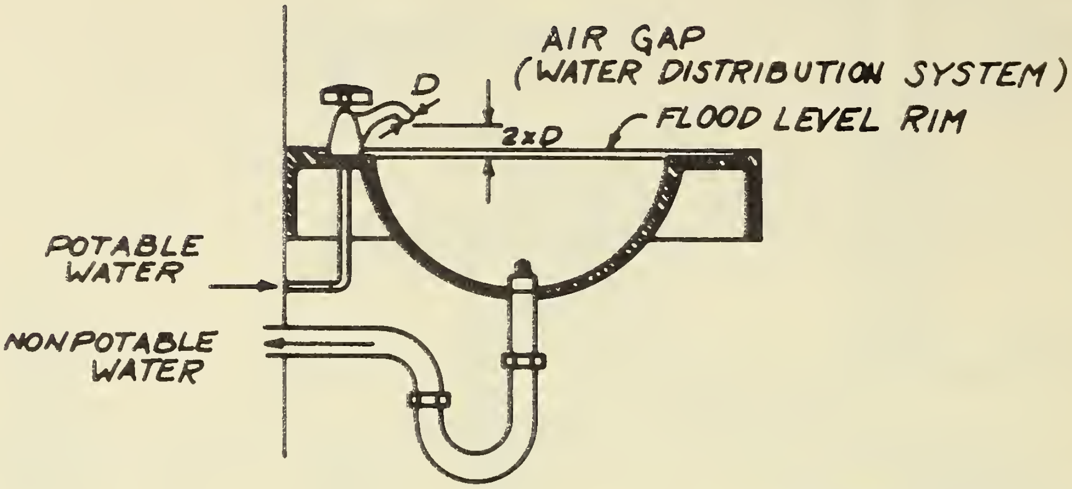


Figure 4-19

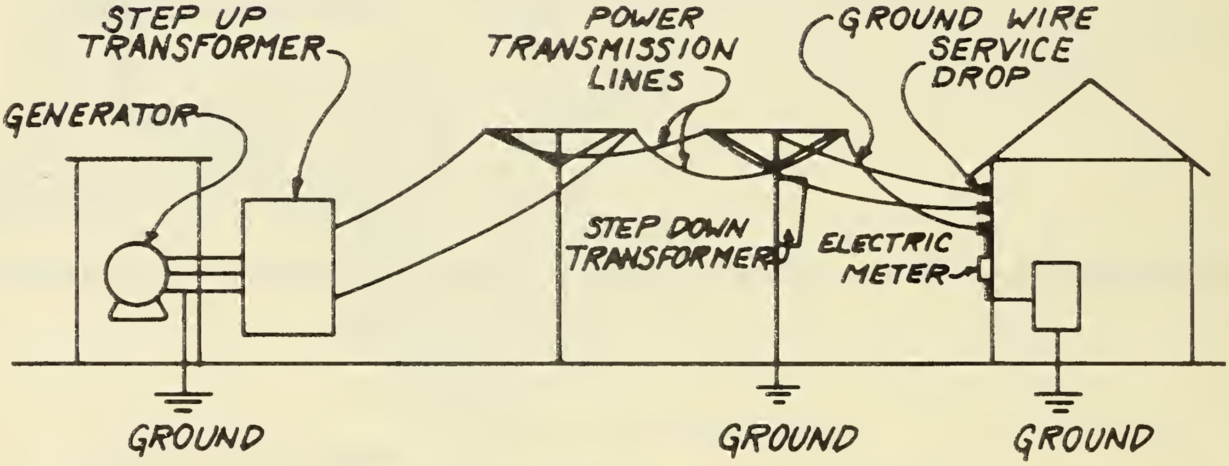


Figure 4-20

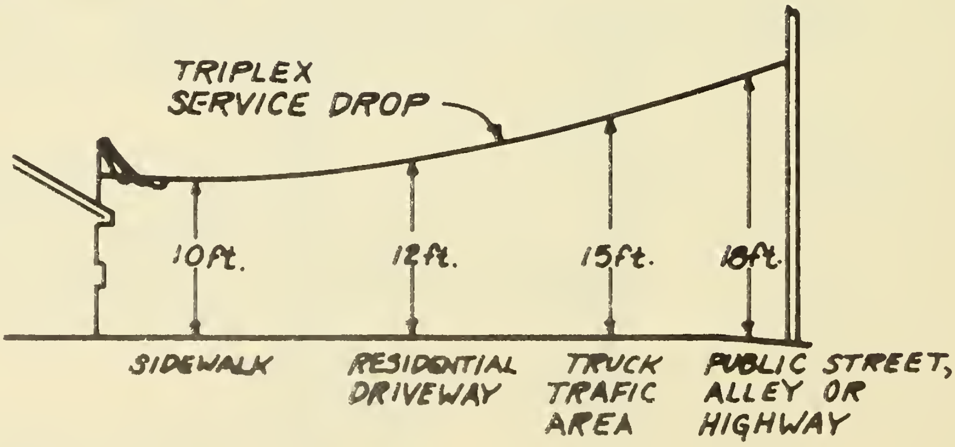


Figure 4-21

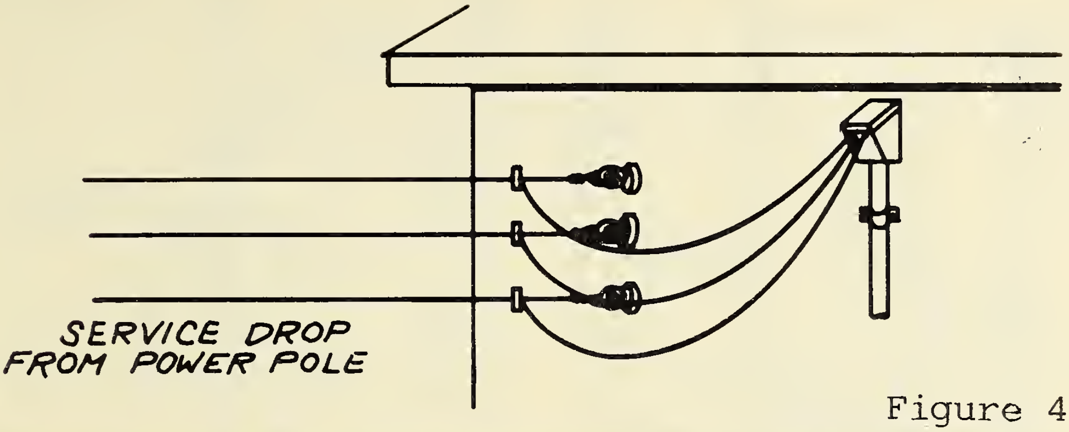
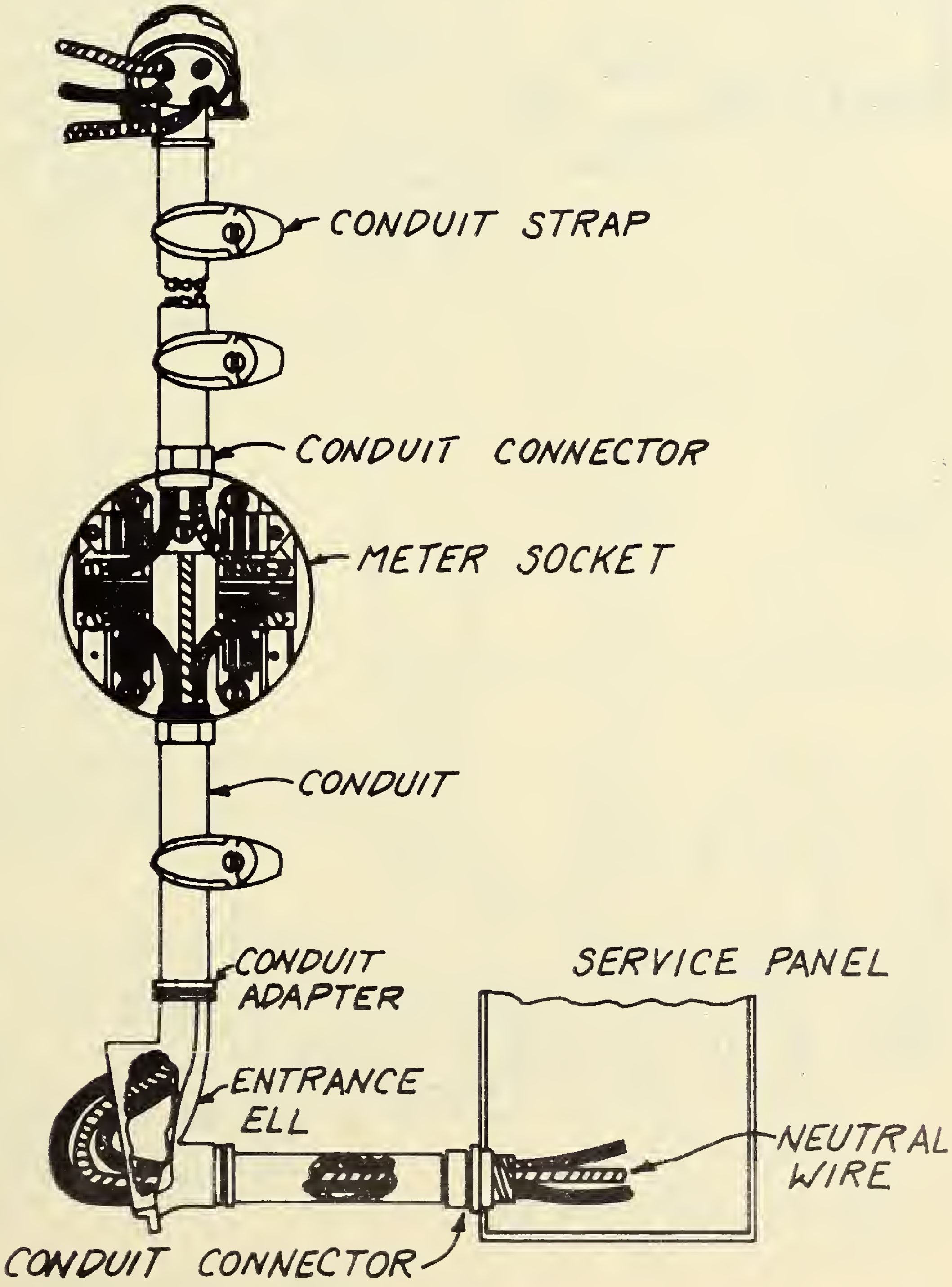
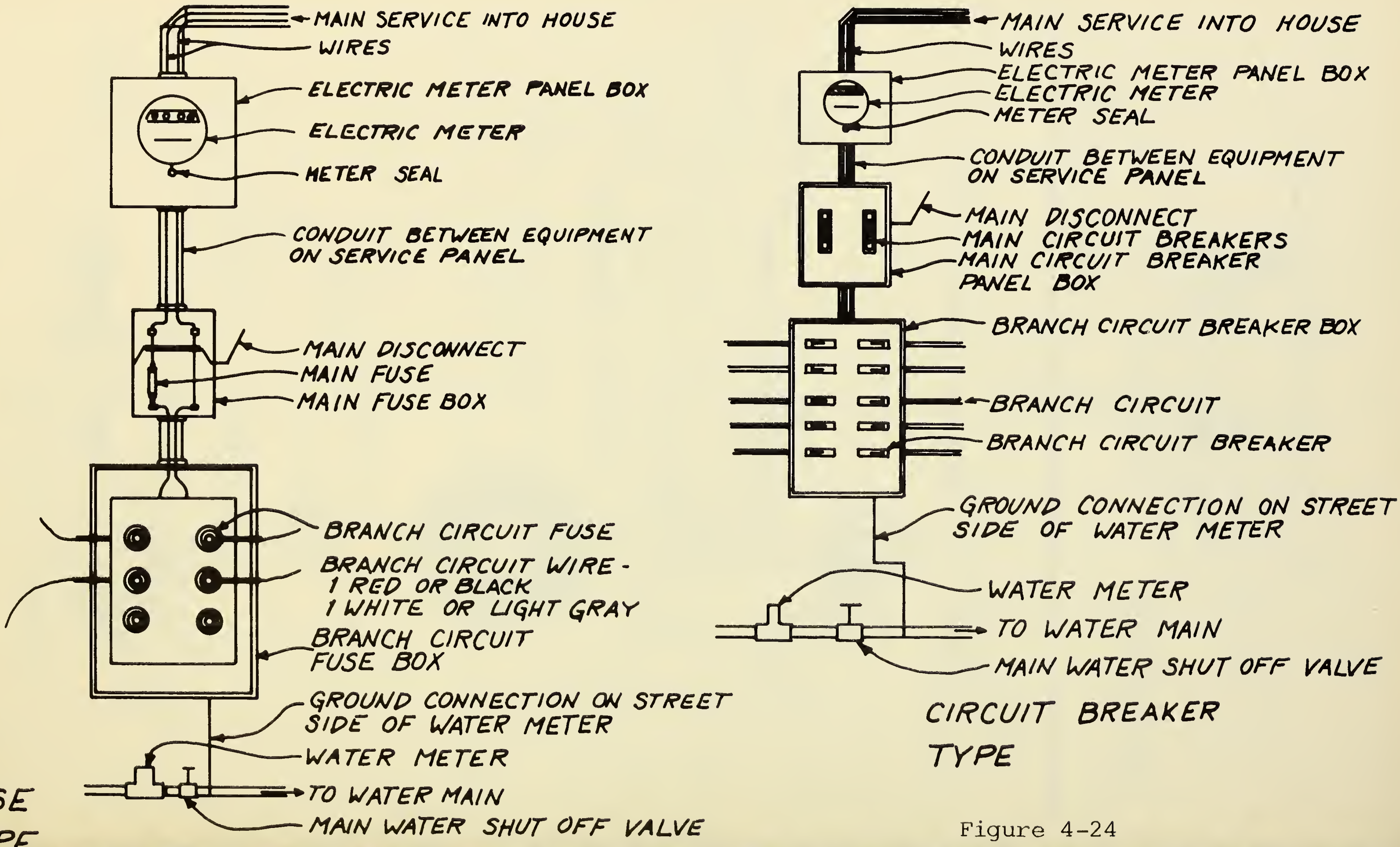


Figure 4-22

Figure 4-23

SERVICE ENTRANCE, CONDUIT TYPE





FUSE TYPE

CIRCUIT BREAKER TYPE

Figure 4-24

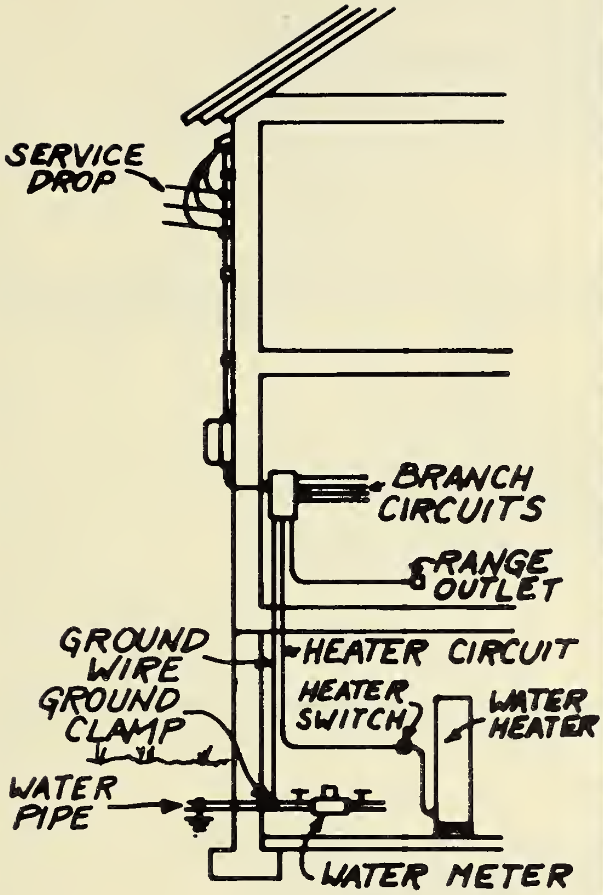


Figure 4-25

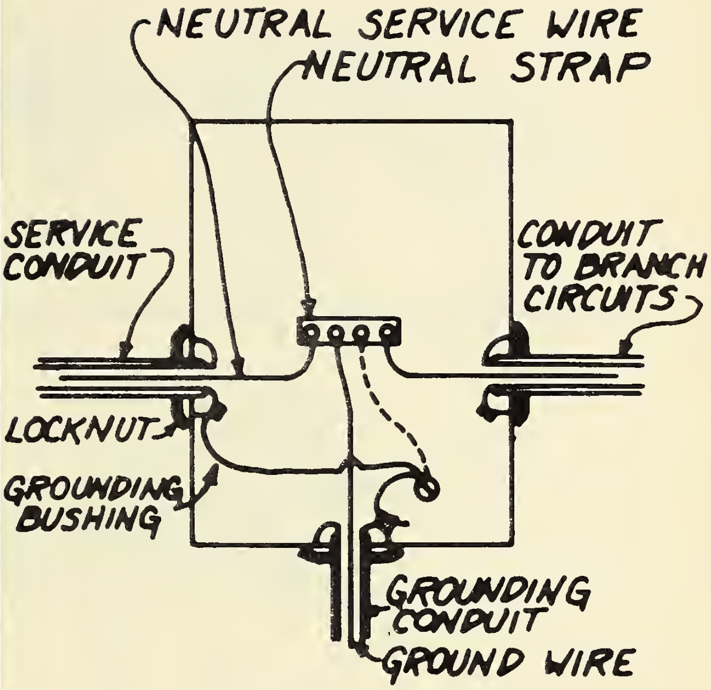


Figure 4-26

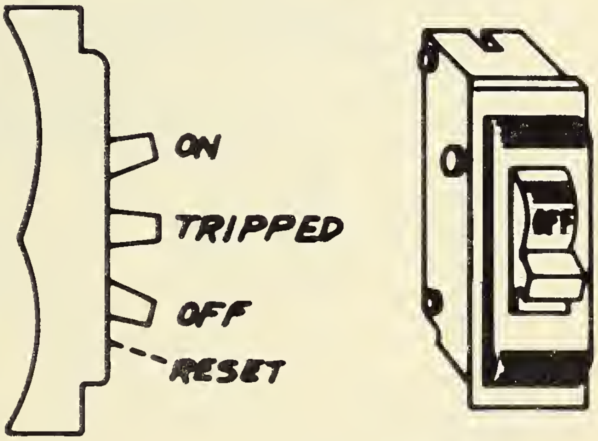
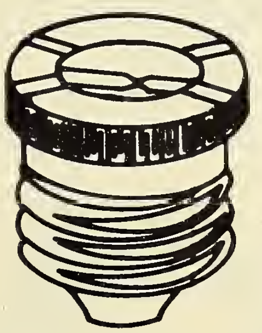
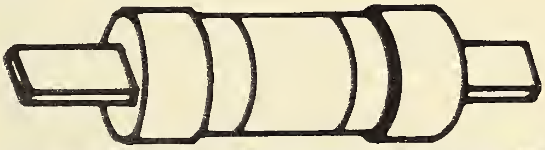


Figure 4-27

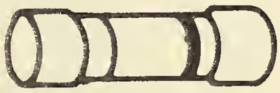


a PLUG FUSES ARE NOT MADE IN RATINGS OVER 30 AMPS.

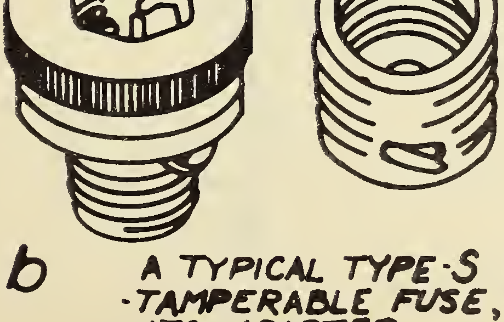


CARTRIDGE FUSES RATED MORE THAN 60 AMP. HAVE KNIFE-BLADE TERMINALS.

c



CARTRIDGE FUSES RATED 60 AMPS. OR LESS ARE OF THE FERRULE TYPE.



b A TYPICAL TYPE-S NON-TAMPERABLE FUSE, AND ITS ADAPTER.

Figure 4-28

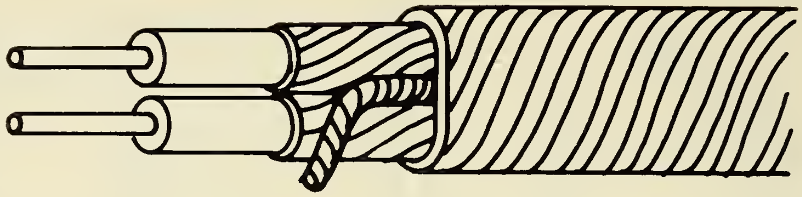


Figure 4-29

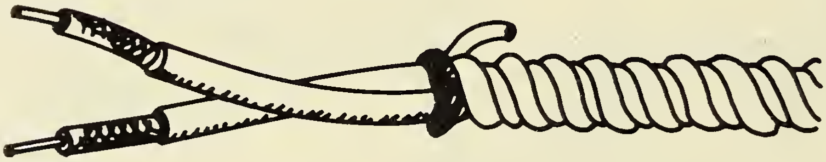


Figure 4-30

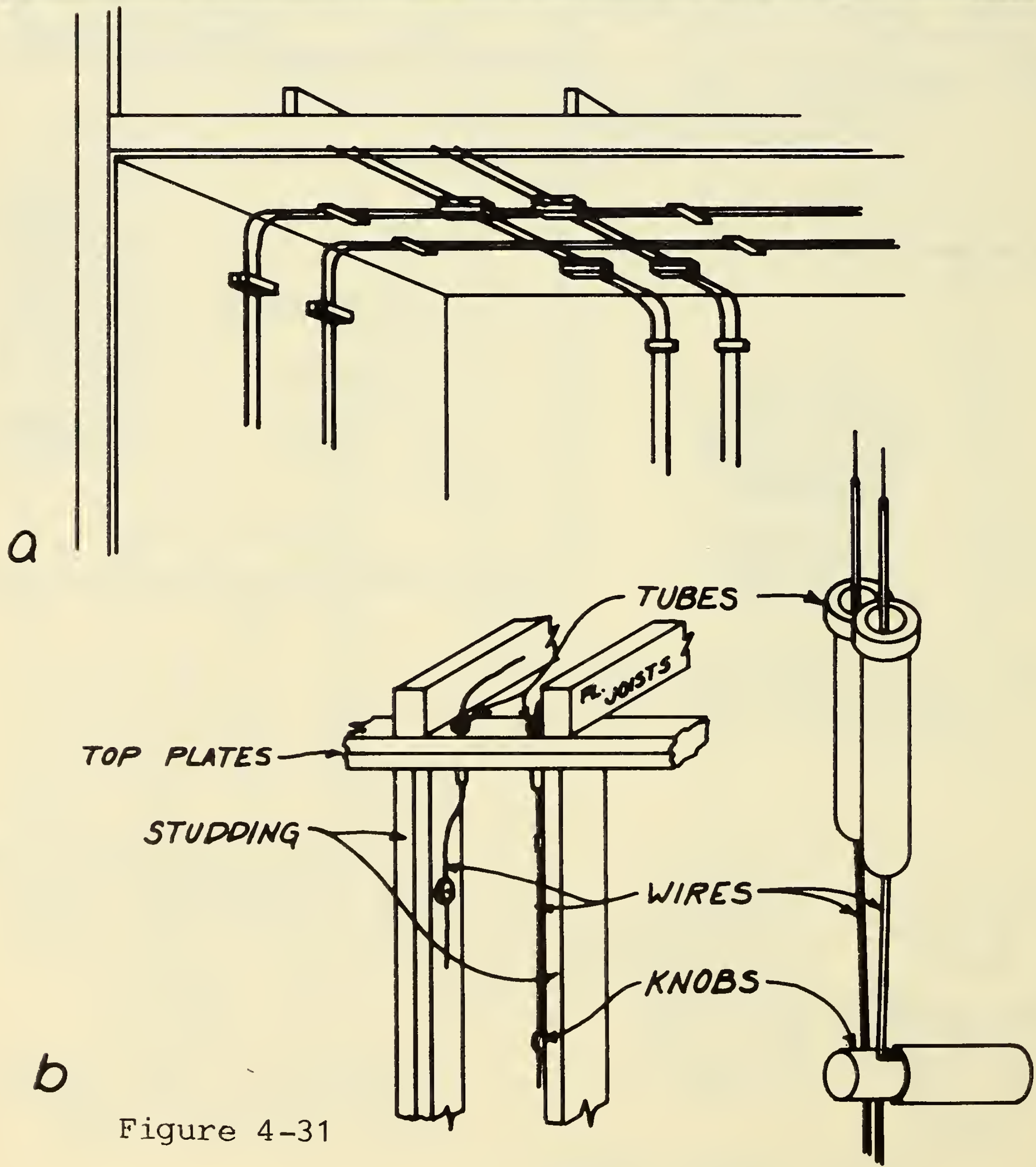
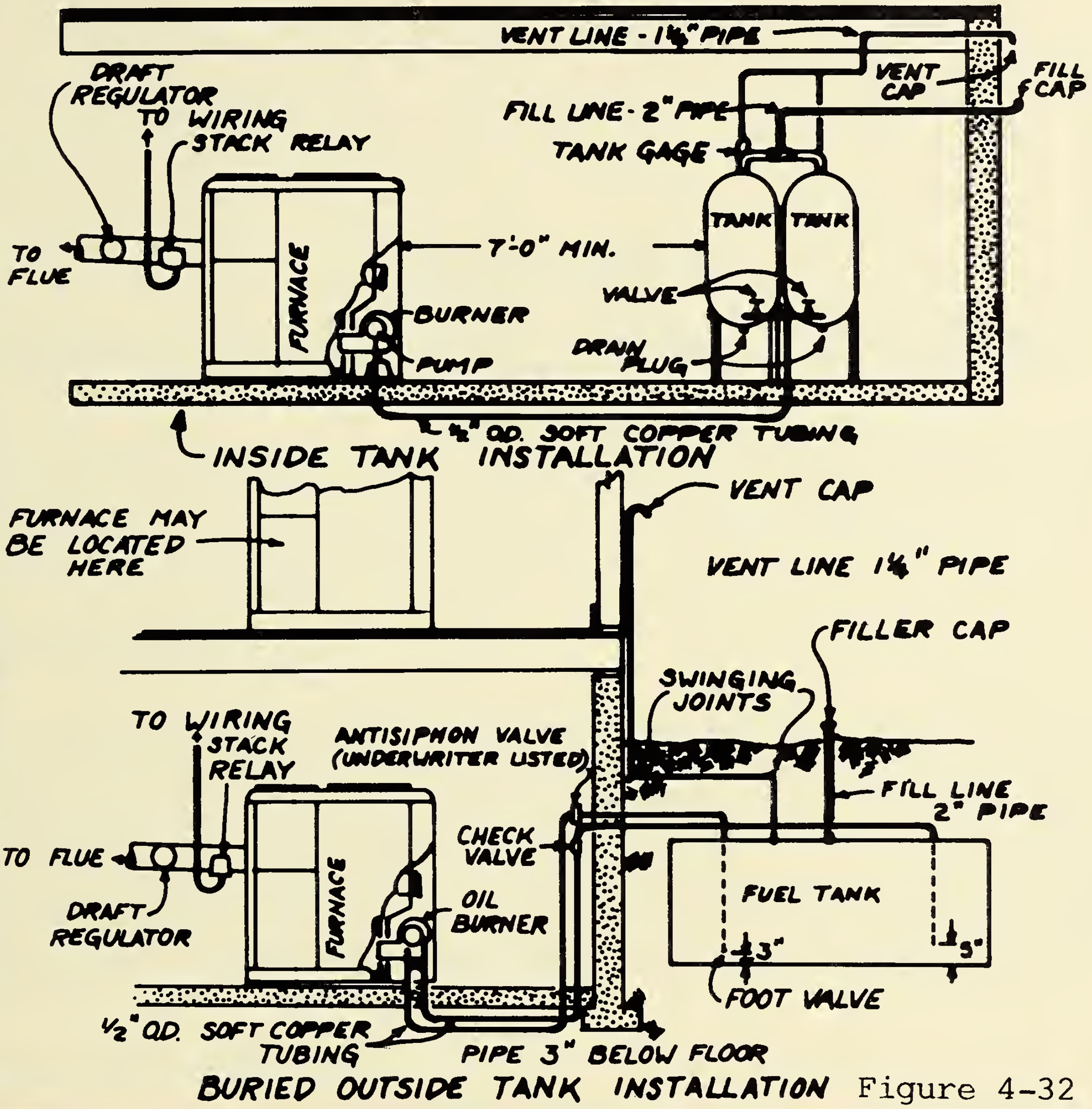


Figure 4-31



NOTE: ENOUGH AIR FOR COMBUSTION MUST ENTER FURNACE ROOM. PROVIDE 15 SQ. IN. OPENING PER GAL. OIL BURNED PER HOUR.

Figure 4-32

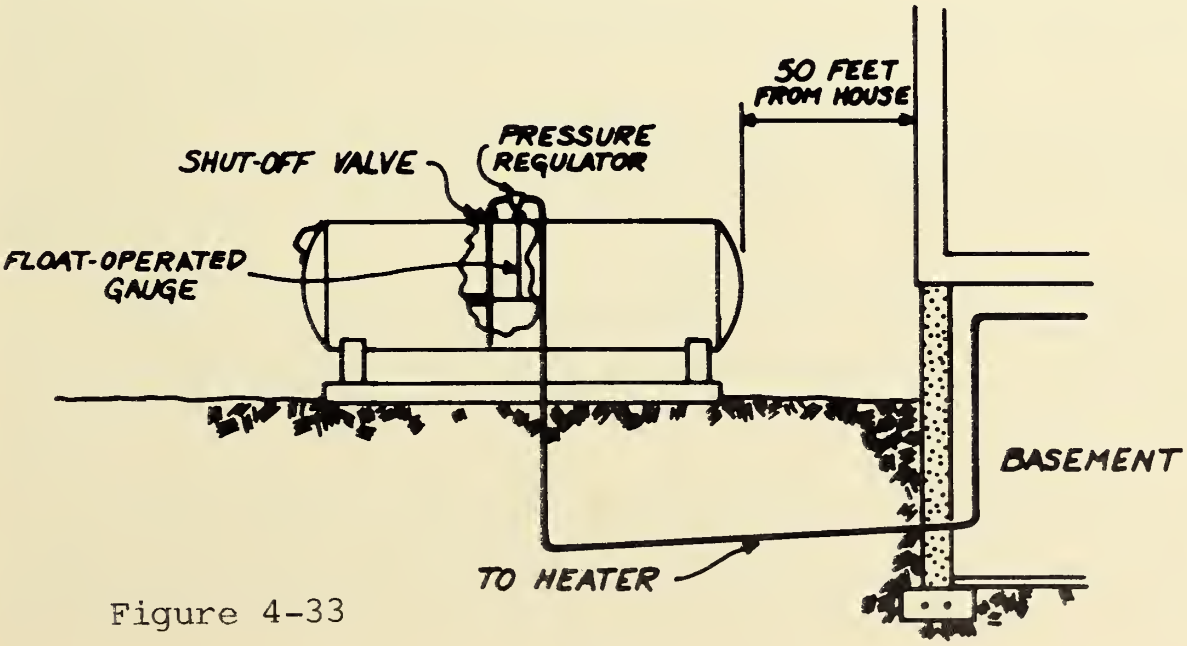


Figure 4-33

CHAPTER V
SAFETY/PROTECTION SYSTEMS

Other considerations covered by Code provisions relate to providing for the safe use of the building by its occupants, whether they be regular inhabitants or transient visitors. These factors are those of circulation, fire safety, security, and protection against natural elements and biological hazards.

CIRCULATION

The patterns used in buildings to provide access to all spaces vary depending on the location (because of climate and topography), use or occupancy (because of the number and type of occupants and their activities), size (because of areas and heights), and the means used or necessary for circulation. Circulation patterns may be horizontal or vertical. One basic distinction is on the basis of providing for the movement of people or goods. The movement may utilize the same means for the two groups or have separate channels. Another distinction is on the basis of Code provisions for required means of circulation for egress (or exit).

Horizontal Circulation

Two categories of horizontal circulation are utilized: direct (dependent on human effort), and assisted (using some form of equipment). Elements of a building comprising the direct category are vestibules, corridors, and doors. The most familiar types of assisted horizontal circulation are: moving walks, for people; and the various types of conveyors for goods.

Vestibules serve to provide an intervening space between the outside environment and the interior of the building because of the weather, the need for control of entry or egress, as a gathering place, or for directional guidance. Lobby, entry, and foyer are other terms used.

Corridors, typically, are long narrow spaces providing access or egress for the rooms or spaces in the building, fully separated by walls or partitions from these rooms. If the space for circulation is not physically separated from the room, normally it's called an aisle. Another type of corridor is the mall, a way for shoppers to move between stores.

Code provisions for corridors generally are based on their possible use as means of egress, discussed in the section on Fire Safety. Minimum fire-resistance ratings required for the walls (and ceilings, in some cases) of corridors are intended to provide protection for occupants seeking escape. These provisions are different for malls since malls are required to have an automatic sprinkler system and a minimum distance between the two sidewalls of the mall far in excess of that normally found in corridors.

Minimum width in the Code for corridors is 44 inches except for one- and two-family dwellings (36 inches); egress requirements will determine a need for greater widths. In malls, the minimum width is 20 feet between opposite shop fronts, with any use of this space for display, etc., increasing this minimum distance. If corridors are used for exit access and vary in elevation less than 21 inches (3 risers), ramps should be used.

Doors are the elements of the horizontal circulation system which provide control of movement, or privacy, between the corridor and room. Code provisions set minimum fire-resistance rating requirments for doors as part of a wall. The desirability for vision-panels in doors may conflict with these fire-resistance ratings; wired glass is the only type allowed in fire-rated doors, in sizes limited by the rating. To ensure that occupants seeking egress in event of emergency cannot be trapped, the hardware type allowed/required are also part of the fire-rating.

There are many styles of doors both for exterior and interior use. Interior doors should offer a reasonable degree of privacy. Exterior doors must, in addition to offering privacy, protect the interior of the structure from the elements. The various parts of a door have the same definitions as the corresponding parts of a window.

In general, the horizontal members are called rails and the vertical members are called stiles. Every door has a top and bottom rail, and some may have intermediate rails. There are always at least two stiles, one on each side of the door (Figure 5-1). The frame of a doorway is the portion to which the door is hinged. It consists of two side jambs and a head jamb, with an integral or attached stop against which the door closes (Figure 5-1).

Exterior door frames are ordinarily of softwood plank, with sides rabbetted to receive the door in the same way as casement windows. At the foot is a sill, frequently made of hardwood to withstand the wear of traffic, and sloped down and out to shed water.

Interior door frames are similar to exterior, except that they are often set directly on the hardwood flooring without a sill.

Widths of doors are set in the codes, 36 inches being minimum. Exterior doors and frames must be substantially weathertight, watertight, and rodent proof, and maintained in sound working condition and good repair. If a door in a dwelling unit opens directly to the outside, it must be provided with a self-closing screen door to lessen the movement of insects to the inside.

The most common types of doors are:

Batten door: This consists of boards nailed together in various ways. The simplest is two layers nailed to each other at right angles, usually with each layer at 45 degrees to the vertical. Another type of batten door consists of vertical boards nailed at right angles to several (two to four) cross strips called ledgers, with diagonal bracing members nailed between ledgers. If vertical members corresponding to ledgers are added at the sides, the verticals are called frames. Batten doors are often found in cellars and other places where appearance is not a factor and economy is desired.

Flush door: Solid flush doors are perfectly flat, usually on both sides, although occasionally they are made flush on one side and paneled on the other. Flush doors sometimes are solid planking, but they are commonly veneered over a core of small pieces of white pine or other wood. These pieces are glued together with staggered end joints. Along the sides, top, and bottom are glued 3/4- inch edge strips of the same wood, used to create a smooth surface that can be cut or planed. The front and back faces are then covered with a 1/8-to 1/4-inch layer of veneer. Solid flush doors may be used on both the interior and exterior.

Hollow-core doors: These, like solid flush doors, are perfectly flat, but unlike solid doors, the core consists mainly of a grid of crossed wooden slats or some other type of grid construction. Faces are 3-ply plywood instead of one or two plies of veneer, and the surface veneer may be any species of wood, usually hardwood. The edges of the core are solid wood and are made wide enough at the appropriate places to accommodate locks and butts. Doors of this kind are considerably lighter than solid flush doors. Hollow-core doors are usually used only as interior doors.

Paneled doors: Many doors are paneled, with most panels consisting of solid wood or plywood, either "raised" or "flat," although exterior doors frequently have one or more panels of glass, in which case they are called "lights." One or more panels may be employed although the number seldom exceeds eight. Paneled doors may be used both on the interior or exterior.

Other types of doors used include: folding doors (generally for closets, equipment areas in the smaller sizes, and to divide sections of a room, in larger sizes); sliding doors (both by-passing, and pocket); revolving, and overhead.

In addition to the various types of wood doors, metal is often used as a veneer or for the frame.

Vertical Circulation

Two categories of vertical circulation also are utilized: direct, and assisted. The elements of a building in the direct category are: ramps, ladders, stairs; and in the assisted category: elevators, and escalators.

In general, ramps have the same provisions as corridors for widths and enclosure, but their surface must be of non-slip material, and if used as exitways, must comply in concept with the requirements for stairways. The slope of a ramp should not exceed 1 foot in height in 8 feet of length; if used by physically-handicapped persons, the maximum slope is 1 foot in 12 feet.

Ladders are not considered an acceptable means of movement in most situations; permitted uses are for those conditions of infrequent use by only one or two people, such as for maintenance or in boiler rooms.

Stairs are treated in the code primarily from the standpoint of egress in the event of fire, although many of these provisions also relate to safe and convenient use for normal purposes.

The general purpose of the standards for stairway dimensions is to ensure that there is adequate headroom, width, and uniformity in riser and tread size of every step to accommodate the expected traffic on each stairway safely (see Figure 5-3).

Interior stairways should be not less than 44 inches in width, which may be reduced to 36 inches in one- and two-family dwellings or if the occupants are less than 50. Stairs with closed risers should have maximum risers of 7¾ inches and minimum tread of 9 inches plus 1-inch nosing, with a ratio of riser to tread such that the sum of 2 risers and 1 tread is between 24 and 25 inches. Basement stairs, often constructed with open risers, have maximum risers of 8¼ inches and minimum treads of 9 inches plus 1/2-inch nosing. The head-room in all parts of the stair enclosure should be no less than 80 inches. Treads and risers should be uniform in any one flight of stairs.

Exterior stairway dimensions should be the same as those called for in interior stairways, except that the headroom requirement does not apply.

Except for one- and two-family dwellings, spiral stairways and winders in stairs are not permitted for exits. Circular stairs may be used for exits if the minimum width of any tread is at least 10 inches, and the inner radius of the stair is at least twice the width of the stair.

Landings in conjunction with stairs must have the same width as the stairs; if a door opens onto a stairway, there must be a landing between the door and the stair.

All stairs having more than 3 risers must have handrails on one side, and must be protected on any open side.

Elevators and escalators make feasible and practical the increase in height of buildings that construction technology made possible. Without some means of providing access to buildings over four stories high, the high-rise building could not have become as significant as it has. The development of automatic operating and safety controls has made it economically feasible to move large numbers of people quickly.

The principal items in any elevator installation include the car, the cables and elevator machinery, control equipment, counterweights, shaft and rails, and the penthouse and pit. The element most familiar to users is the car, a light metal cage on a structural frame moving in a vertical path determined by the rails. Two types of elevator traction machinery are used: geared for low rise buildings not needing high speed operation (50-350 fpm) and gearless for buildings over 100 feet in height (over 400 fpm).

Although a well-designed elevator installation should be able to move all occupants of an office building within 35 minutes, or of an apartment house in one hour, elevators do present problems. In the past, elevators frequently were accepted by building Codes as part of the required exit system for buildings. The standards for elevators now referenced by the Code do not accept them as exits, partly as a result of the automatic controls installed in recent years which have eliminated the human operator capable of exercising judgement in crisis. An elevator responding to a call might open onto the floor of the fire. Although the Code requires that the shaft have a 2-hr rating, the doors cannot provide the same degree of fire-resistance, and the shaft effectively may function as a chimney. If power failed during a fire, the safety controls would automatically hold the car at that location, trapping any passengers. The safety controls also prevent the car from moving with the doors open, and prevent the doors from shutting until clear of people attempting to board. In panic, no one might escape from a floor.

Current Code provisions call for all cars to return to the entrance floor for high-rise buildings, the cars must be available for use by the fire department for access to higher floors for operations and evacuation.

Possible solutions to some of these problems, although not currently provided for in the Codes, might involve creating fire-safe lobbies separating the elevator shafts from the remainder of each floor; incorporating fire-detection controls within the call-system to prevent a car stopping at a floor exposed to fire; and providing emergency power for elevator operation and for pressurizing the shafts and lobbies, to reduce their "chimney" effect.

Escalators, unlike elevators, provide vertical movement in a continuous flow without waiting. The shaft for the elevator must be vertical; escalators can be staggered in their vertical relationship. The Code permits the escalators designed for movement in the direction of egress to be included in the exit system. However, the openings in the floors still present a hazard unless "enclosed" by one of several methods involving sprinkler protection.

FIRE SAFETY

In 1974, the United States suffered losses totaling $4 billion and 12,000 lives as a result of fires, not including costs of fire department and insurance company operation, costs of loss of business, nor the injuries caused occupants and firefighters. The aims in fire safety are to provide life safety, property protection, and continuity of operations, aims which have been met by providing adequate means of escape, protecting the structure long enough to permit evacuation and extinguishment, containing the fire within the area of origin.

Outside of human behavior, fire is the most complicated phenomenon that is encountered in buildings. Structure, plumbing, and ventilation are tame phenomena, well-behaved and predictable, but fire is a combination of chemistry, geometry, structure, and materials that is intimately connected with human behavior.

Fire or combustion can be considered to be a chemical reaction dependent on three elements: fuel, oxygen, and source of energy. It produces, in addition to flame and heat, smoke, toxic gases, superheated gases, and a deficiency of oxygen. The major part of the deaths and injuries occurring in fires are caused by these 'by-products' rather than the flames and heat.

Fire growth occurs in six stages:

ignition initiation
initial item development
intra-spatial development
intra-compartment development
inter-compartment development
inter-building development

Ignition initiation begins with the introduction of an energy source (a match) to the fuel, since oxygen is always present in the air. At this stage, the contents of a building constitute the fuel normally, rather than the materials of construction and the Code enforcement official has only limited knowledge and little authority over the contents. Since the effectiveness of a material as fuel depends on its thermal inertia, ignition temperature, shape and surface area/volume, the Codes do have provisions as to the quantity of certain materials considered hazardous.

In the second stage, initial item development, the fire increases until the original fuel-source is consumed.

The third stage begins with the spread of the fire to a second fuel-source, until all fuel-sources in the room-of-origin are involved. As additional sources are involved, the fire grows at an increased rate, complicated by the phonomenon of 'flashover' which results when the surfaces of the room reach the same temperature as the fire. If this occurs, the temperature in the room increases rapidly and significantly, as does the energy of the fire.

In the fourth stage, if the energy of the fire is great enough, the fire may spread to rooms adjacent to the room-of-origin if the room surfaces provide insufficient barrier. If the fire spreads beyond the room-of-origin, it may continue spreading until it reaches barriers adequate to contain it for a period of time.

If these barriers eventually fail to contain the fire because of poor thermal resistance, incompleteness, or structural collapse, the fire continues to spread throughout the building (the fifth stage). If the characteristics of the exterior surfaces of the building are not adequate, the fire can then spread in the sixth stage to adjacent buildings.

The objectives of fire safety are to increase the potential of disrupting the development of the fire, and to reinforce the survival of the occupants in each stage. Figure 5-4 illustrates the factors involved in providing fire-safety by controlling those factors which tend toward self-termination of a fire, which should function together to support each other.

An example of this relationship can be seen with the first two elements: volume of the room, and height. A low ceiling height tends to reinforce the fire while a large volume tends to disrupt its development. Four major factors contribute to the rate of burning: the geometry of the room, fuel load, the nature of the barriers, and ventilation. A low ceiling tends to cause the flames to spread horizontally, as do walls close to the fire (as is more likely in small rooms). The greater the volume of a room, the less likely that the fire will flashover.

The third item, furnishings, includes all of the contents of a room, or the fuel. How the contents are located in the room, their distribution, contributes to either reinforcing or disrupting the fire, but again in most cases, the code enforcement official has little knowledge or control. The volume of a room may provide a clue, since in larger rooms, the contents are more likely to be dispersed, and disrupt fire growth.

The nature of the contents affects the tendencies of the fire. In addition to limitation on the quantities of certain materials, codes also limit the nature of plastics and other materials used in the room for interior finish, based on tests of flame spread and smoke and toxics generated (see Table 5-1).

A major emphasis of the codes is to require suitable materials in the construction, in terms of their fire-resistance, the protection systems used, and their non-combustibility.

Ventilation, the ratio of window area to floor area, interrelates with the fuel load in determining the severity of a fire. If the volume of air is low, the flame increases in height, and flashover is more likely (unless the oxygen is so low that the fire terminates). If, however, the ventilation is excessive, the flame height is governed by the fuel and geometry, and flashover is less likely to be as rapid. The proportions of the windows and the likelihood of closed doors have an effect on ventilation.

Compartmentation refers to the provision of fire-resistive barriers to contain the fire within the area of origin (Figure 5-5). Codes contain provisions both as to the degree of fire-resistance needed under certain conditions and the amount of area allowable within barriers (Table 5-2). Under normal occupancy, each tenant should have 1 hour separation from other, except that multiple small tenants are considered adequately separated within 3,000 square feet between 1 hour walls. Attic and under floor spaces in combustible construction need ½ hour separation-barriers every 3,000 square feet if unsprinklered, or 8,000 square feet if sprinklered.

The thermal resistance of the wall (the first major factor) determines how rapidly the heat of the fire will be transmitted to adjoining rooms. If resistance is low, heat will be transmitted rapidly, possibly increasing spread of the fire to an adjoining room, and if thermal resistance is high, the temperature of the surfaces in the room-of-origin will increase rapidly and flashover is more likely.

A second characteristic required of barriers is their structural strength or integrity, their ability to resist the force of the fire for the prescribed period of time and remain intact, not allowing burn-through. The third characteristic is that of completeness, the continuity of compartmentation provided. Codes require that such walls, for instance, be continuous from the surface of one floor through to the underside of the fire-resistant surface above. Quality of workmanship enters here in determining actual completeness, as well as the rating of the finishes.

However, completeness is also dependent on the nature and amount of openings in the barrier. Since doors are required for circulation, doors and frames in barriers are required by the code to have fire-resistant ratings consistent with that of the wall, with means of assuring closure. If flashover occurs in a room, the glass in any windows will probably be blown out, and therefore the spacing of openings becomes critical to prevent spread of fire to adjoining spaces. Another type of opening through barriers occurs with the passage of ductwork. Completeness of the barrier is provided through installation of firedampers in the duct. Unintentional penetration of the barrier may be provided by sloppy installation of piping or electrical conduit without sealing the space between the piping and the edges of the barrier, as required by all of the relevant codes.

If a fire starts, a second approach for protection in addition to compartmentation (which merely contains the fire) is that of suppression (Figure 5-6) closely allied to detection. Inasmuch as manual suppression by the occupants is highly dependent on alertness, training and equipment, the codes contain provisions for major reliance on fire department intervention. In terms of disrupting the growth of the fire, however, installation of automatic suppression systems provides more rapid response, and code provisions contain certain 'bonuses' if such systems are installed where not required. Their response is generally dependent on detection of the heat of the fire, and the growth of the fire can be disrupted at an earlier stage if selective smoke detection is used.

Several types of suppression systems are available. Automatic sprinkler systems, (Figure 5-7) using water as the extinguishing medium, may be installed in several modes: dry pipe (in which water is present in the piping only when fire has activiated the system); wet pipe (in which water is always present, for immediate release when needed for extinguishing); deluge (in which water is admitted to the system by separate controls, for release over an entire area); and preaction (in which a separate detection system controls the flow of water into the system to be released through an activated sprinkler head). A sprinkler head is activated when a pre-determined temperature is reached (ranging from 135° to 575°) at its location, and thus a fire may be underway before suppression occurs. However, the positive protection received from an automatic sprinkler system is the basis for code requirements, and for use in providing equivalent safety where other safety provisions are not obtainable in existing buildings.

Other suppression systems, such as foam, halon, carbon monoxide, etc., are used where the use of water might worsen the fire conditions or where damage from water would be undesirable.

Detection can serve not only to begin suppression, but also to provide warning to the occupants to begin evacuation, and also inform the fire department (Figure 5-8).

All of the topics discussed so far are means toward meeting the three aims of fire safety: life safety, property protection, and continuity of operations, since limiting the area involved in a fire and providing for rapid suppression will allow the normal use of the building to resume sooner, and also reduce the hazard to life. However, satisfactory provision for life safety necessitates means for the occupants either to evacuate rapidly and safely, or to be safe in a location within. Codes have provisions requiring completeness of the path of exit, that it have adequate capacity for the occupants, that access to the path be direct, and that the path be safe for those seeking escape or taking refuge (Figure 5-9).

In high-rise buildings, the length of time required for vertical movement becomes excessive (Figure 5-10). Areas of refuge must be provided within the building if the nature of the occupants, as in hospitals, precludes evacuation.

Egress is a type of circulation; the codes establish requirements for those components of the circulation system used for egress. A means of egress has three elements whether horizontal and/or vertical: exit access (those components of the circulation system leading to an entrance to the exit); the exit itself, separated from other areas of the building by protected surfaces, and leading to the exterior of the building; and exit outlets, if required, to lead directly from the exit to the street or outside space. (Figure 5-11).

The number of exits that must be provided is based on the number of occupants (Table 5-3). Other than for those rooms or areas where a firm number of occupants can be demonstrated, the code provides data for calculation (Table 5-4). This exit capability must be maintained throughout the entire exit path. The code requires at least two means of egress from any space in the building, with certain exceptions for small areas, and for rooms having less than 50 occupants.

Capacity of the means of egress (Table 5-5) is based on research of 60 years ago on the movement capabilities of human beings, based on an average mix of age, sex, and physical condition. This rate of movement differs for horizontal and vertical modes, and is changed for those occupancy or use types where freedom of movement is limited either by physical condition (as in hospitals), or by restraints (as in prisons), or where greater freedom is necessary to avoid delay (as in hazardous occupancies). The rate is given in terms of the number of people moving in a travel path 22 inches in width (based on dimensions of the body) in one minute of time. Although the code requires provisions for access to every building for handicapped people, no pressure has been brought to provide comparable means of egress, nor to recognize the slowing effect of the presence of the established rate.

Associated with rate of movement are the code provisions concerning maximum travel distance to an exit (Table 5-6), which can be increased if additional protection from the flames and the heat of the fire is provided by an automatic suppression system, which will disrupt the growth of a fire impending the path of travel and also cool the surface surrounding the exit path.

The exit path must be a protected-way. If enclosed, it must be separated from the remainder of the building; if exterior to the building, as in balconies or exterior stairways, the path of movement cannot be endangered by passing unprotected openings. To protect those using stairs, the fire-rated enclosure must include the underside of a stairway (except in one-or two-family dwellings).

In some cases, as in high rise business and residential buildings, and all institutional occupancies, horizontal exits may serve for 50% of the exit capacity required, to allow the occupants of one part of the building to move to an area of refuge on the same level protected by at least a two-hour smoke partition.

The exit path should be direct, and fairly obvious. For this reason, dead-end corridors (not leading to any means of exit) cannot be longer than 20 feet. Similarly, the means of egress must be illuminated (if above a minimum number of occupants) by an emergency lighting system, and the exit itself must be identified by illuminated exit signs and directional signs as necessary (Table 5-7).

Dwelling units, in the Housing Code, must have a safe unobstructed means of egress to a safe open space at ground level. The Building Code requires that each sleeping room in one-and two-family dwellings have, in addition to the room door, one window or door for emergency egress or rescue, operable without separate tools. This window must have 5.7 square feet of clear opening.

An office building may serve to summarize the provisions for means of egress. The building is business occupancy; Table 5-4 indicates that occupant content is calculated on the basis of 100 gross square feet per person. If each floor in the five story building has an area of 20,000 square feet, there would be 200 occupants/floor (20,000/100). The two required exit stairs which must be remotely located from each other, must have a capacity to move 100 persons each. Each stair must be 44" wide (2 unit-widths), since

200/2 = 100, and 1 unit-width in Table 5-5 for stairs provide capacity for only 60 persons. The 44″ wide stairs would allow for movement of 120 persons. The exit door into the stair enclosure and the exit access corridor must be the minimum allowed width of 36″ (1½ unit-widths), which provides for a capacity of 150 (100 x 1½). (Table 5-5.)

Since the exit stairs are within 20′ from the ends of the corridor, the dead-end limitation is met, and total corridor length between exits is 300 feet. Table 5-6 indicates that the maximum distance allowed for travel to an exit if the building is unsprinklered is 150 feet; a person exiting from an office midway along the corridor can reach an exit within the allowed travel distance (300/2 = 150′).

With 200 occupants/floor, illuminated exit signs are required (200/150) in Table 5-7, but no directional signs are necessary since the exit signs would be visible from any point along the corridor. However, exit illumination with emergency power would be necessary for the exit access corridor.

SECURITY

Security is a concern in buildings to protect the contents, including the occupants, from intrusion by unauthorized persons, whether for stealing, arson, vandalism, or assault. This concern increases for those periods when the building may be unoccupied. The approaches available are somewhat analagous to those for fire safety: compartmentation, providing construction of increased resistance to unauthorized entry; detection, to detect any intrusion in the absence of direct control by the occupants, and give alarm; and by suppression, to deter intrusion by providing equipment or devices limiting entry. Unfortunately, some of the solutions used for any of these purposes may produce conflict with fire-safety provisions; for example, devices intended to limit entry may also hinder egress in event of fire, if both criteria are not used during selection.

Prevention of entry through doors and windows has normally been accomplished by locks. The only code provisions relevant are those dealing with means of egress, providing that locks shall not require use of any tools (including keys) for egress. In most cases, entry is obtained using keys, although other means such as magnetic cards are used for controlled entry through doors not under direct observation, and electric locks opened by actuation at a remote location. In some cases, electric locks with a "fail-safe" provision have been approved for required exit doors remote from visual control as in a library, if connected to the fire detection system and with a sign indicating the nature of the operation.

Other means are used for windows to prevent entry by breaking glass or entering if the window itself is open for ventilation. Grilles, shutters, or other screening units are frequently used, either fixed or movable, even though in dwellings, egress through windows in sleeping rooms is required to provide the second exit required by the code. Use of break-resistant plastic panels in lieu of glass might provide one solution.

Detection of unauthorized entry can be accomplished by several means, most of which are more reliable than squeaking floors, and which are not covered by code provisions other than meeting pertinent requirements of the National Electrical Code. Photo-electric cells and light sources, ultrasonic radiation, pressure-sensitive mats, and vibration-sensitive tape are but a few of the means available.

ENVIRONMENTAL

Protection should be provided in the building against those aspects of the environment outside the building which may cause damage to the structure, enclosure, or contents of the building. Water, in the subsurface ground, surface drainage, and rain or snow is one factor; temperature, a second; and lightning, the third.

Subsurface water may have two effects: pressure may cause structural problems and defects; and seepage into the interior causes mildew, decay, or other damage. Pressure can best be handled as part of the structural design of the foundations, by the installation of expansion-joints permitting the sections of the building to move without violating the continuity of the surface, and by providing drainage at the footing level.

Surface water may leak into the building or cause rotting of wood, and is best prevented by grading so that the flow of water is away from the building and by installing an adequate drainage system (Figure 5-12). In addition, if surface water does not flow but remains standing, health problems can ensue.

The dangers of puddles and pools of stagnant water can be great depending on the location, the depth, and amount of the stagnant water. Stagnant water, whether it is on the ground or in receptacles such as cans, bottles, or rubber tires, can be a major health hazard in any area of the country. Mosquitoes use these pools as breeding grounds. Female mosquitoes lay their eggs in water, and the eggs hatch into a larvae stage. The larvae later change to a pupal stage and remain in the water-filled container until they change into adult mosquitoes, and begin the fourth stage of their life cycle. It is in this fourth, or adult, stage that mosquitoes can carry disease to man. The elimination of ponds, puddles, and other sources of stagnant water is the best way of eliminating mosquito hazards. If the pond or pool is large enough, it can also be a safety hazard for small children who may stumble into the water and drown.

Poor drainage may create another hazard if electricity is nearby. The obvious danger of being electrocuted exists when water and electricity are both present. The inspector should always look for evidence of water near the main fuse box in the house, and for broken or frayed electrical wires in the kitchen, bathroom, water closet compartment, or laundry room.

Excessive dampness, caused by puddles or other small bodies of stagnant water or leaking plumbing fixtures, can cause structural damage to a house. The water itself can cause rotting of main structural members, or can offer the campground needed by subterranean termites for their attack on wooden structures.

Drainage of water from the roof should be provided for, either by adequate roof overhang and gravel surfacing on the ground underneath, or by gutters (Figure 5-13).

Gutters and rain leaders should be placed around the entire building to ensure proper drainage of water. This will lessen the possibility of seepage of water through siding and window frames, and entrance of water into the cellar or basement. Gutters and leaders should be of noncombustible materials. They should be securely fastened to the structure and spill into a storm sewer if one is available. When there is no storm sewer, a concrete or stone block placed on the ground beneath the leader prevents water from eroding the lawn. This block is called a splash block. Lack of or leaking gutters may result in rotting of the siding or erosion of the exposed portion of the cellar or basement walls. The situation commonly exists where the mortar between bricks or concrete blocks in the foundation walls is found to be heavily eroded. They should be free from dirt and leaves. Gutters will not become plugged if protected against clogging of leaves and twigs. Gutters should be checked every spring and fall and then cleaned out when necessary.

In locations where two surfaces or two different materials adjoin, water may enter the building even though structural integrity may have been maintained. Recent practice calls for flashing at more points than previously considered necessary, as a result of poor experiences with the damaging effects of water entering the building as it "opened up" due to movement or shrinkage. In many cases, a single flashing-member is unacceptable for these two reasons, and flashing and counter-flashing should be used.

Flashing should be used at the junction of a roof and a wall, in roof valleys, at chimneys, over exposed doors and windows, at siding-material changes, and other areas such as vents in the roof for the plumbing system, where rain or melted snow may penetrate into the house. In many cases, flashing will be concealed, but in some situations, it must be exposed. In either case, suitable materials must be used, and installed properly.

Materials most commonly used are galvanized metal, terneplate, aluminum, copper, stainless steel, bituminous-coated fabric, and more recently, some of the plastics. Near the seacoast, where the salt in the air may corrode galvanized sheet metal, copper or stainless steel is preferred for gutters, downspouts, and flashings. Aluminum is not normally used when it comes in contact with concrete or stucco unless it is protected with a coat of asphaltum or other protection against reaction with the alkali in the cement.

The types of metal fastenings, such as nails and screws, and the hangers and clips used with the various metals, are important to prevent corrosion or deterioration when unlike metals are used together. For aluminum, only aluminum or stainless steel fasteners should be used. For copper flashing, use copper nails and fittings. Galvanized sheet metal or terneplate should be fastened with galvanized or stainless-steel fasteners.

When a roof intersects a vertical wall, flashing is used at the junction. These tin or galvanized-metal shingles are bent at a 90° angle and extend up the side of the wall over the sheathing a minimum of 4 inches (Figure 5-14a). When roofing felt is used under the wall finish, it is turned up on the wall and covered by the flashing. One piece of flashing is used at each shingle course. The siding is then applied over the flashing, allowing about a 2-inch space between the bevel edge of the siding and roof.

If the roof intersects a brick wall or chimney, the same type of metal shingle flashing is used at the end of each shingle course as described for the wood-sided wall. In addition, counterflashing or brick flashing is used to cover the shingle flashing (Figure 5-14b). This counterflashing is often preformed in sections and is inserted in open mortar joints.

A wood saddle, usually constructed on the high side of wide chimneys for better drainage, is made of a ridge-board and post and sheathed with plywood or boards (Figure 5-15). It is then covered with metal, which extends up on the brick and under the shingles. Counterflashing at the chimney is then used.

Stack vent and roof ventilators are provided with flashing collars which are lapped by the shingles on the upper side. The lower edge of the collar laps the shingles. Sides are nailed to the shingles and caulked with roofing mastic.

The valley formed by two intersecting rooflines is usually covered with metal flashing . Some building regulations allow the use of two thicknesses of mineral-surfaced roll roofing in place of the flashing.

Widths of sheet-metal flashing for valleys should not be less than:

12 inches wide for roof slopes of 7 in 12 and over.

18 inches wide for 4 in 12 to 7 in 12 roof slopes.

24 inches wide for slopes less than 4 in 12.

The width of the valley between shingles should increase from the top to the bottom (Figure 5-16).

When adjacent roof slopes vary, such as a low-slope porch roof intersecting a steeper main roof, a 1-inch crimped standing seam should be used (Figure 5-16). This will keep heavy rains on the steeper slopes from overrunning the valley and being forced under the shingles on the adjoining slope.

One wall area which requires flashing is at the intersection of two types of siding materials. For example, stucco-finish and wood-siding should be flashed (Figure 5-17a). A wood molding such as a drip cap separates the two materials and is covered by the flashing which extends behind the stucco. The flashing should extend at least 4 inches above the intersection. When sheathing paper is used, it should lap the flashing.

When a pattern change in wood-siding occurs on the same wall, the intersection should also be flashed (Figure 5-17b). When the upper wall, such as a gable end, projects slightly beyond the lower wall, flashing is usually not required.

The same type of flashing shown in Figure 5-17a should be used over door and window openings exposed to driving rain. However, window and door-heads protected by wide overhangs in a single-story house with a hip roof do not ordinarily require such flashing. When building paper is used on the sidewalls, it should lap the top edge of the flashing. To protect the walls behind the window sill in a brick veneer exterior, flashing should extend under the masonry sill up to the underside of the wood sill.

The desirability of providing lightning protection for a particular building depends to a great degree on its location. The frequency and severity of thunderstorms, and the isolation of the building are major factors to be considered. There is no known method to prevent occurrences of lightning. The basic principle is to provide a metallic path-to-ground for the stroke of lightning. This prevents the passage of lightning through the nonconducting portions of the building, which is accompanied by mechanical forces and great heat.

SANITARY

Health considerations provide the basis for code provisions relating to means to prevent the entry of rodents, vermin, and insects into buildings, and for limiting accumulation of trash and garbage on the property.

The presence of vectors such as arthropods (flies, mosquitoes, fleas, cockroaches, lice, mites, ticks, and bedbugs) and rodents (rats and mice) in a building and its premises result from neglect of basic responsibilities for cleanliness. Rodents and arthropods are vectors of disease and cause injury to humans. On the other hand, rats and mice, or insects and other arthropods may not necessarily pose an immediate disease threat, but they are often present in such numbers or in such places as to limit the enjoyment and utilization of our environment. In this sense, they are pests disturbing the well-being of man, and inspection and control programs are justified on this basis alone.

Food, harborage, and water, which are life essentials for arthropods and rodents, occur frequently in and around all types of buildings whenever these vectors prevail. Their numbers increase rapidly as standards of cleanliness and maintenance decline. Substandard residential housing and commercial establishments produce and maintain greater and more widespread vector populations than well kept, clean residential and commercial areas. Lack of knowledge, carelessness, and indifference are usually the basic reasons for such conditions.

Every occupant of a dwelling must maintain the part of the dwelling unit that he occupies and controls. The storage and disposal of rubbish and garbage in a safe and sanitary manner is considered the responsibility of the occupant insofar as the garbage and trash is generated in his portion of the structure. It is the owner's responsibility to see that arrangements are made by the tenant for the adequate removal of this refuse.

In a structure containing three or more dwelling units it is also the owner's responsibility to supply containers for the storage of refuse and to make provisions for its safe and sanitary removal as often as it is necessary to maintain a sanitary structure.

As previously stated, avoiding the attraction of insects and rodents is essential to the public healh. Refuse furnishes food and harboring places for rodents and insects and tends to attract them to areas where they have not previously been present. The requirement that the proper facilities for the storage of rubbish be provided is to fix responsibility for maintenance and use of these facilities with a particular party whether it be the owner or the occupant of the dwelling.

MINIMUM INTERIOR FINISH CLASSIFICATION

OCCUPANCY	UNSPRINKLERED			SPRINKLERED		
	Exits	*Exit Access*	*Other Spaces*	*Exits*	*Exit Access*	*Other Spaces*
A-Assembly	A	A	B	B	C	C
B-Business	B	B	C	C	C	C
E-Educational	A	B	C	B	C	C
F-Factory	C	C	C	C	C	C
H-Hazardous	Sprinklers Required			B	C	C
I-Institutional-						
Restrained-	A	A	B	A	A	B
Unrestrained	Sprinklers Required		B	B	C	C
M-Mercantile	B	B	C	C	C	C
R-Residential	B	B	C	C	C	C
S-Storage	C	C	C	C	C	C

Class A Interior Finish: Flame Spread 0-25, Smoke Developed 0-450.
Class B Interior Finish: Flame Spread 26-75, Smoke Developed 0-450.
Class C Interior Finish: Flame Spread 76-200, Smoke Developed 0-450.

TABLE 5-1

TYPE OF AREA	ALLOWABLE AREA	RATING
Normal Occupancy	See Area Standard Building Code	4 hr.
Between Tenants	3,000 sq. ft.	1 hr.
Attic and Floor Spaces of combustible construction		
(unsprinklered)	3,000 sq. ft.	½ hr.
(sprinklered)	9,000 sq. ft.	½ hr.

TABLE 5-2

MINIMUM NUMBER OF EXITS

Minimum Number of Exits	Occupancy Load
2	50-500
3	501-1000
4	More than 1000

EXCEPTIONS: ONE EXIT PERMITTED:

OCCUPANCY	Area/ Floor	Max. Stories	Max. Travel	Max. Occup.	Remarks
Residential (R)	3,500	2	30′		4 Units/
Business (B)	3,500	2	75′	40	Floor
Mercantile (M)	2,250	1	50′		Occupants Above Street Level
Storage (S)	2,500	1	50′		Street Level

TABLE 5-3

CAPACITY OF MEANS OF EGRESS

OCCUPANCY	PERSON PER UNIT (22 INCHES) OF EXIT WIDTH	
	Level Travel (Corridors, Doors, Ramps, Etc.)	*STAIRS*
Group R-Residential	100	75
B-Business	100	60
E-Schools	100	60
I-Institutional (Restrained)	30	22
I-Institutional (Unrestrained)	30(45)*	22(34)*
M-Mercantile	100	60
A-Assembly	100	75
S-Storage	100	60
F-Factory	100	60
Industrial	100	60
H-Hazardous	50	30

*With approved sprinkler system

TABLE 5-5

OCCUPANT CONTENT

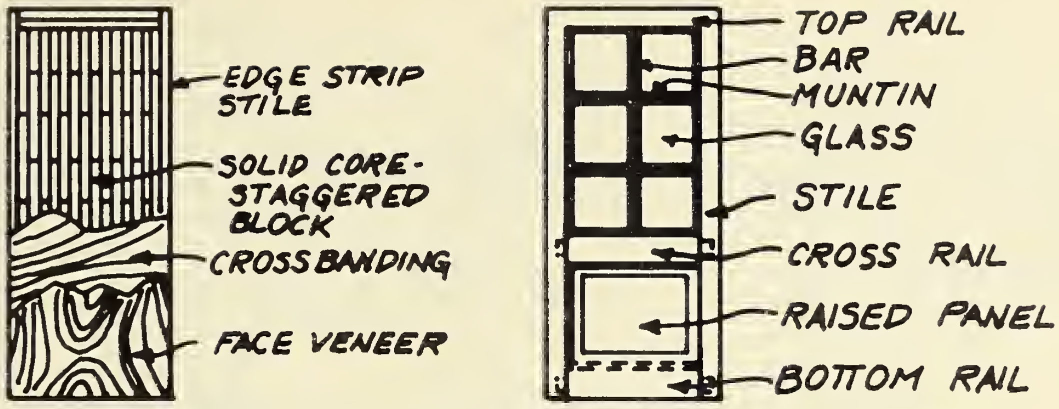
USE	AREA PER OCCUPANT (Sq. Ft.)
Assembly without fixed seats	
Concentrated	7 Net
Standing space	3 Net
Unconcentrated	15 Net
Assembly with fixed seats	# Seats
Bowling Alleys, allow 5 persons for each alley, including 15 feet of runway and for additional areas	7 Net
Business Areas	100 Gross
Restaurants	15 Net
Court Rooms—other than fixed seating areas	40 Net
Educational	
Classroom areas	20 Net
Shops and other vocational areas	50 Net
Industrial Areas	100 Gross
Institutional	
Sleeping areas	120 Gross
Inpatient treatment areas	240 Gross
Outpatient area	100 Gross
Library	
Reading rooms	50 Net
Stack area	100 Gross
Mercantile	
Basement and grade floor areas	30 Gross
Areas on other floors	60 Gross
Storage, shipping area	100 Gross
Parking garage	200 Gross
Residential	200 Gross
Storage area, mechanical	300 Gross

TABLE 5-4

MAXIMUM DISTANCE OF TRAVEL TO AN EXIT, IN FEET

OCCUPANCY	*UNSPRINKLERED*	*SPRINKLERED*
Group A-Assembly	150	200
Group B-Business	150	200
Group E-Educational	150	200
Group H-Hazardous	NP	75
Group F-Factory-Industrial	150	200
Group I-Institutional	NP	200
Group M-Mercantile	150	200
Group R-Residential	150	200
Group S-Storage	150	200
Open Parking Structures	200	200

TABLE 5-6



SOLID CORE DOOR

GLASS & WOOD PANEL DOOR

Figure 5-1

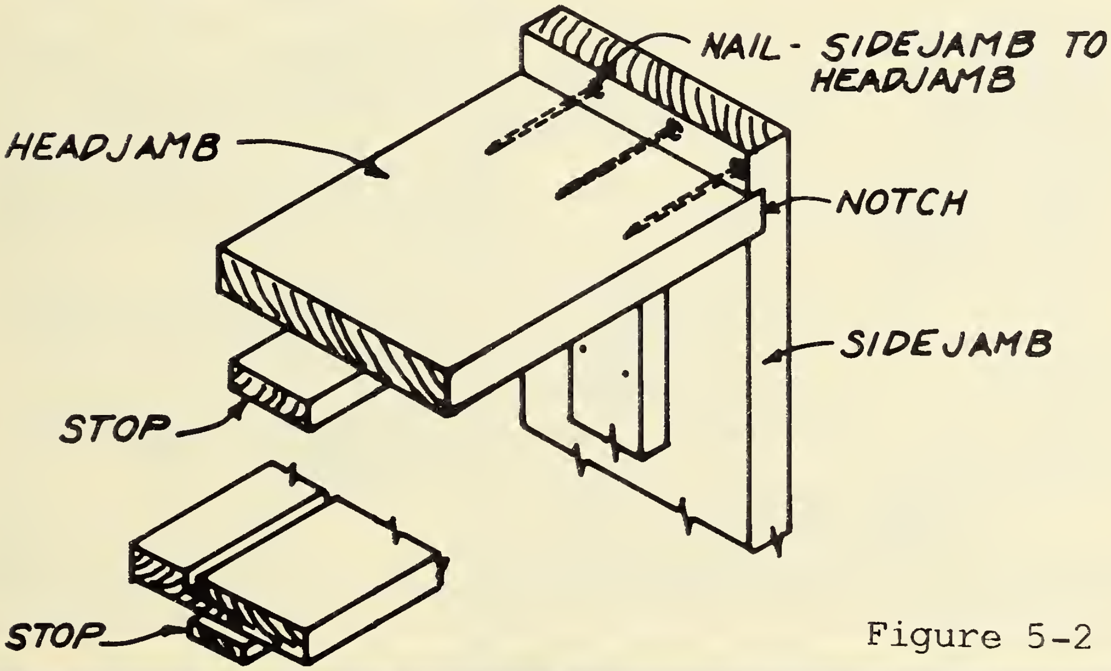


Figure 5-2

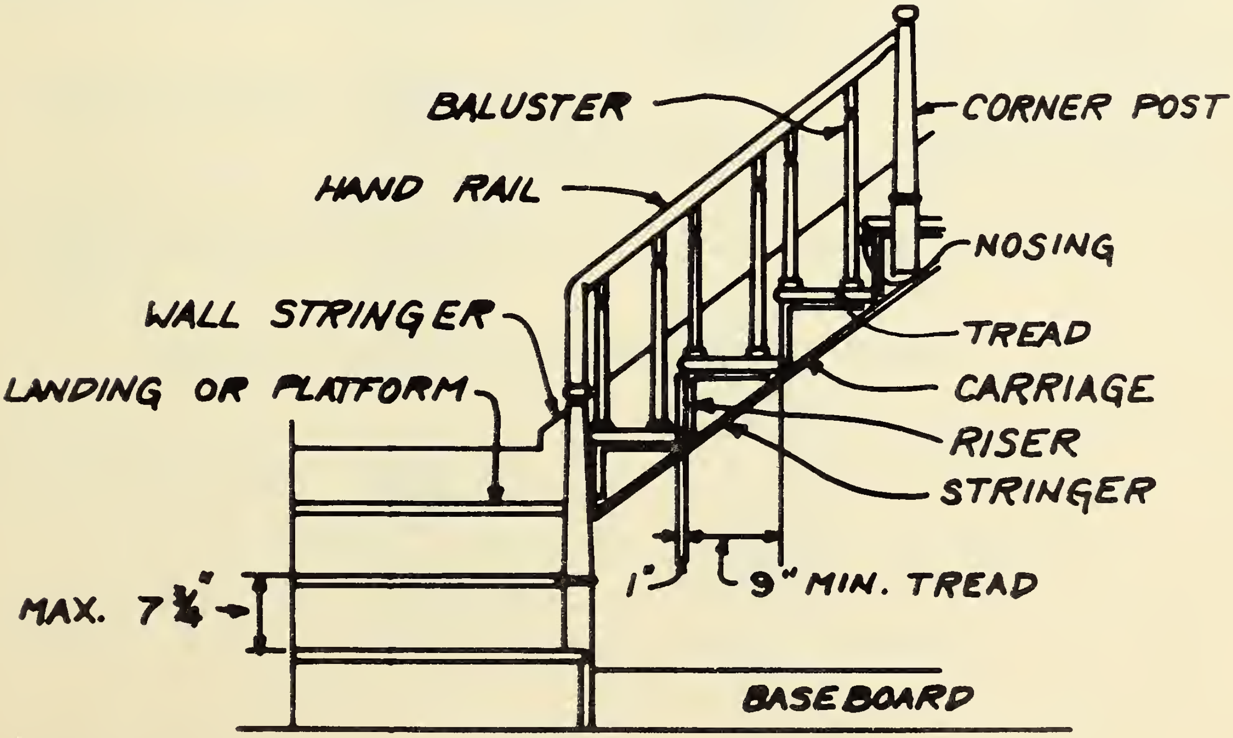


Figure 5-3

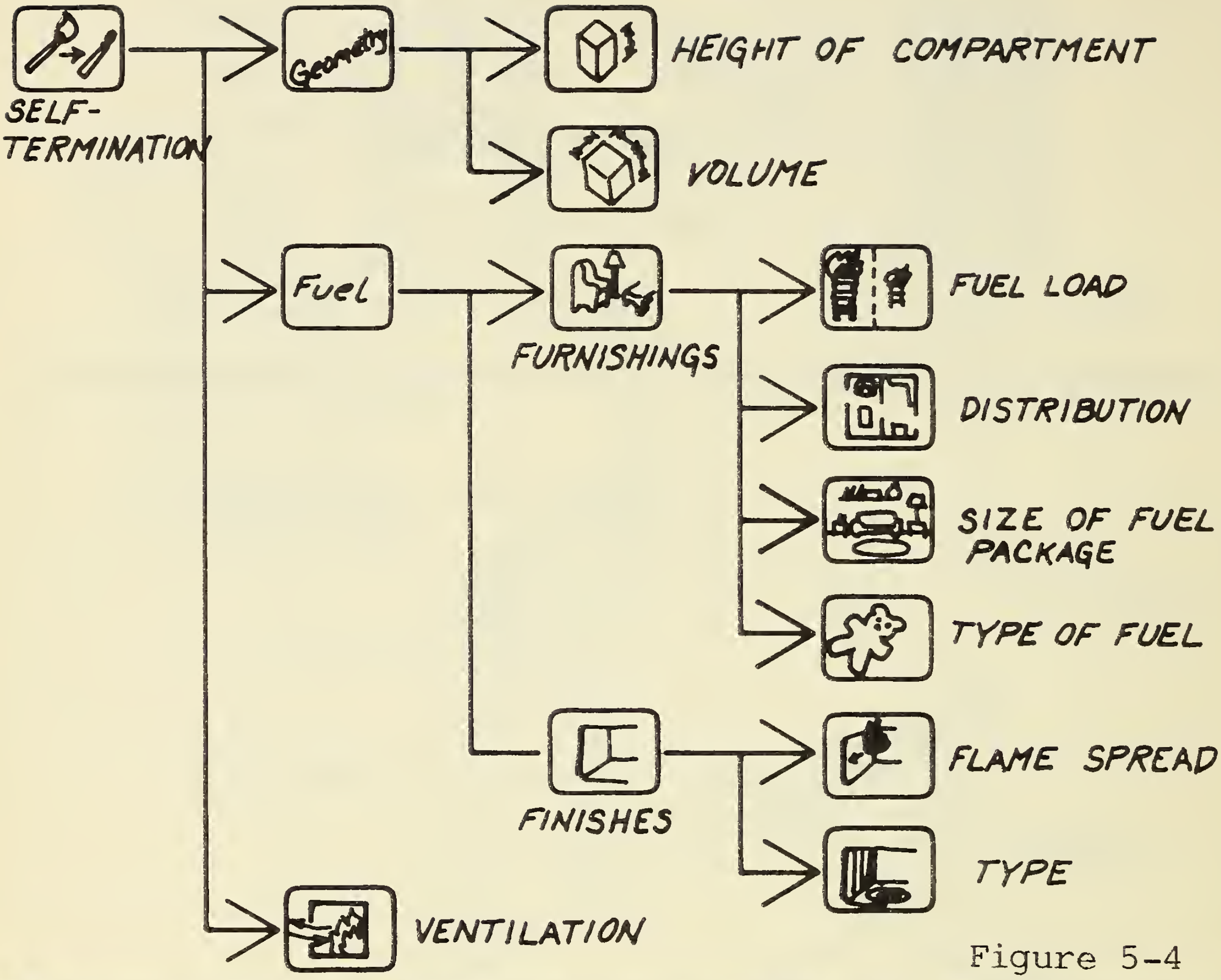


Figure 5-4

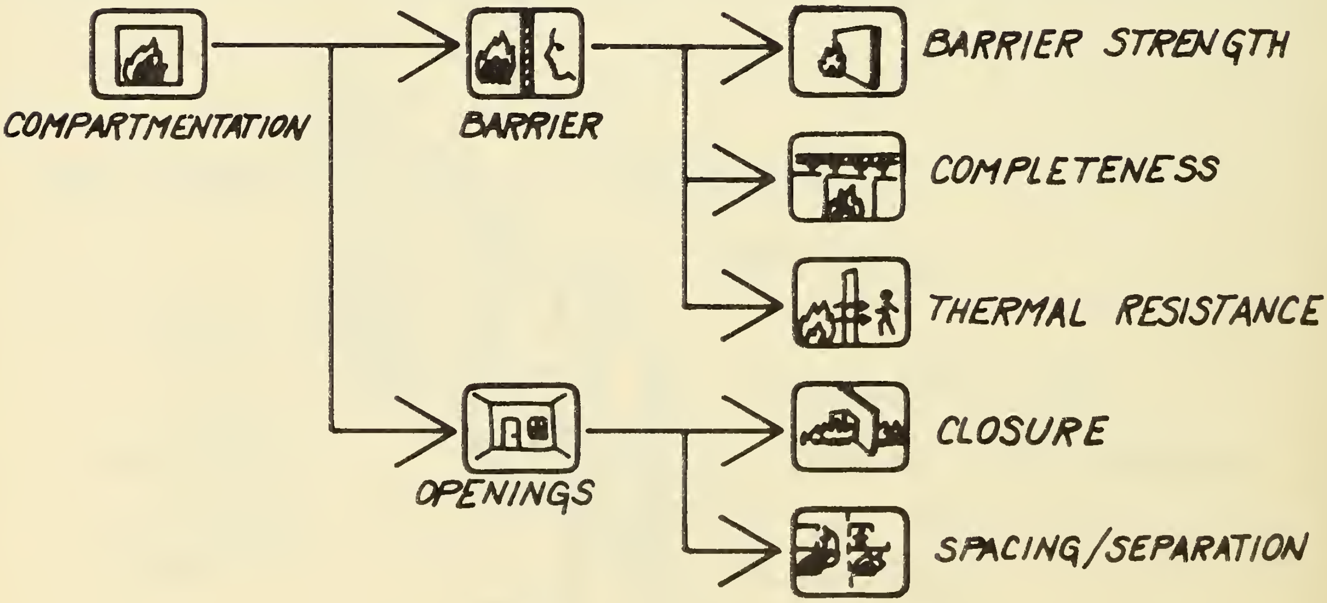


Figure 5-5

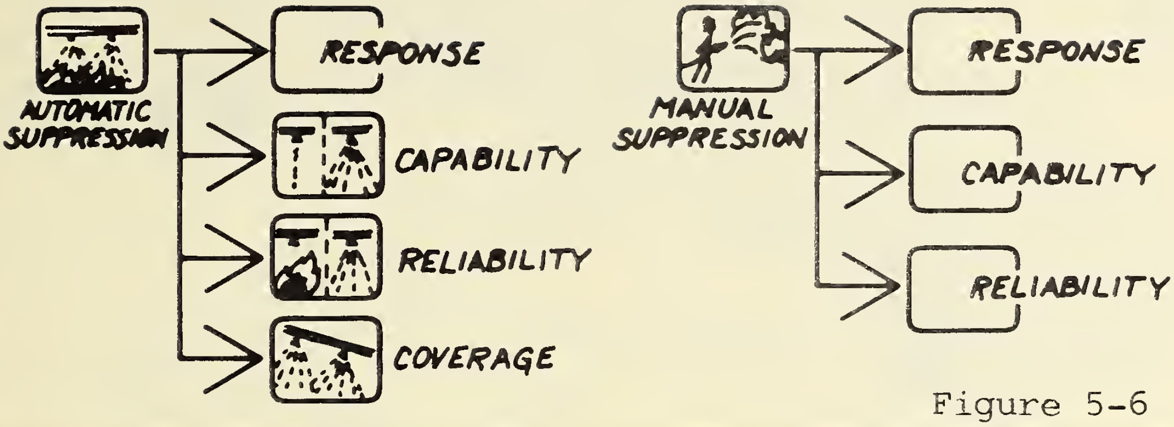


Figure 5-6

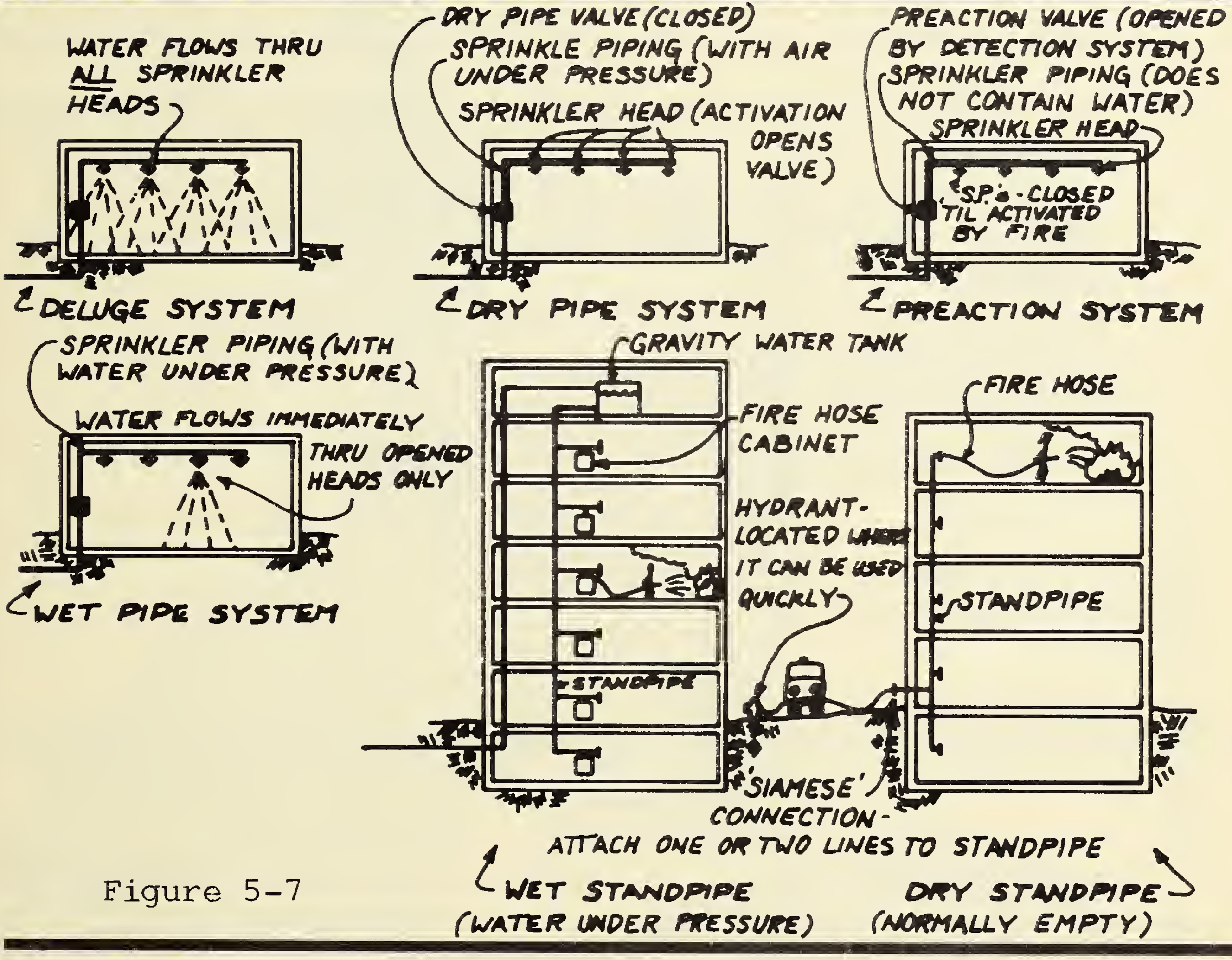

WATER FLOWS THRU ALL SPRINKLER HEADS
DELUGE SYSTEM
DRY PIPE VALVE (CLOSED)
SPRINKLE PIPING (WITH AIR UNDER PRESSURE)
SPRINKLER HEAD (ACTIVATION OPENS VALVE)
DRY PIPE SYSTEM
PREACTION VALVE (OPENED BY DETECTION SYSTEM)
SPRINKLER PIPING (DOES NOT CONTAIN WATER)
SPRINKLER HEAD
SP's - CLOSED 'TIL ACTIVATED BY FIRE
PREACTION SYSTEM
SPRINKLER PIPING (WITH WATER UNDER PRESSURE)
WATER FLOWS IMMEDIATELY THRU OPENED HEADS ONLY
WET PIPE SYSTEM
GRAVITY WATER TANK
FIRE HOSE CABINET
HYDRANT- LOCATED WHERE IT CAN BE USED QUICKLY
STANDPIPE
FIRE HOSE
STANDPIPE
'SIAMESE' CONNECTION - ATTACH ONE OR TWO LINES TO STANDPIPE
WET STANDPIPE (WATER UNDER PRESSURE)
DRY STANDPIPE (NORMALLY EMPTY)

Figure 5-7

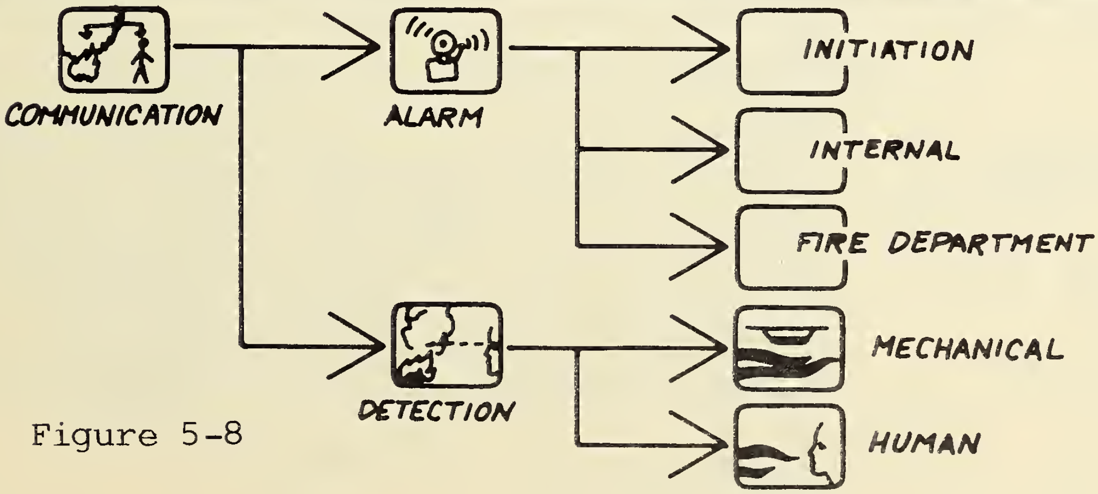


Figure 5-8

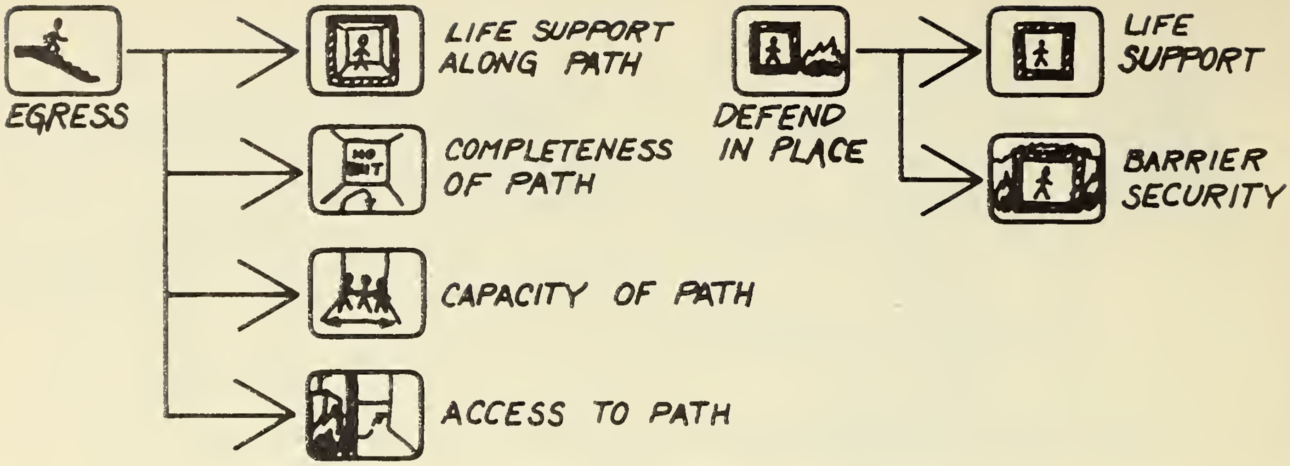
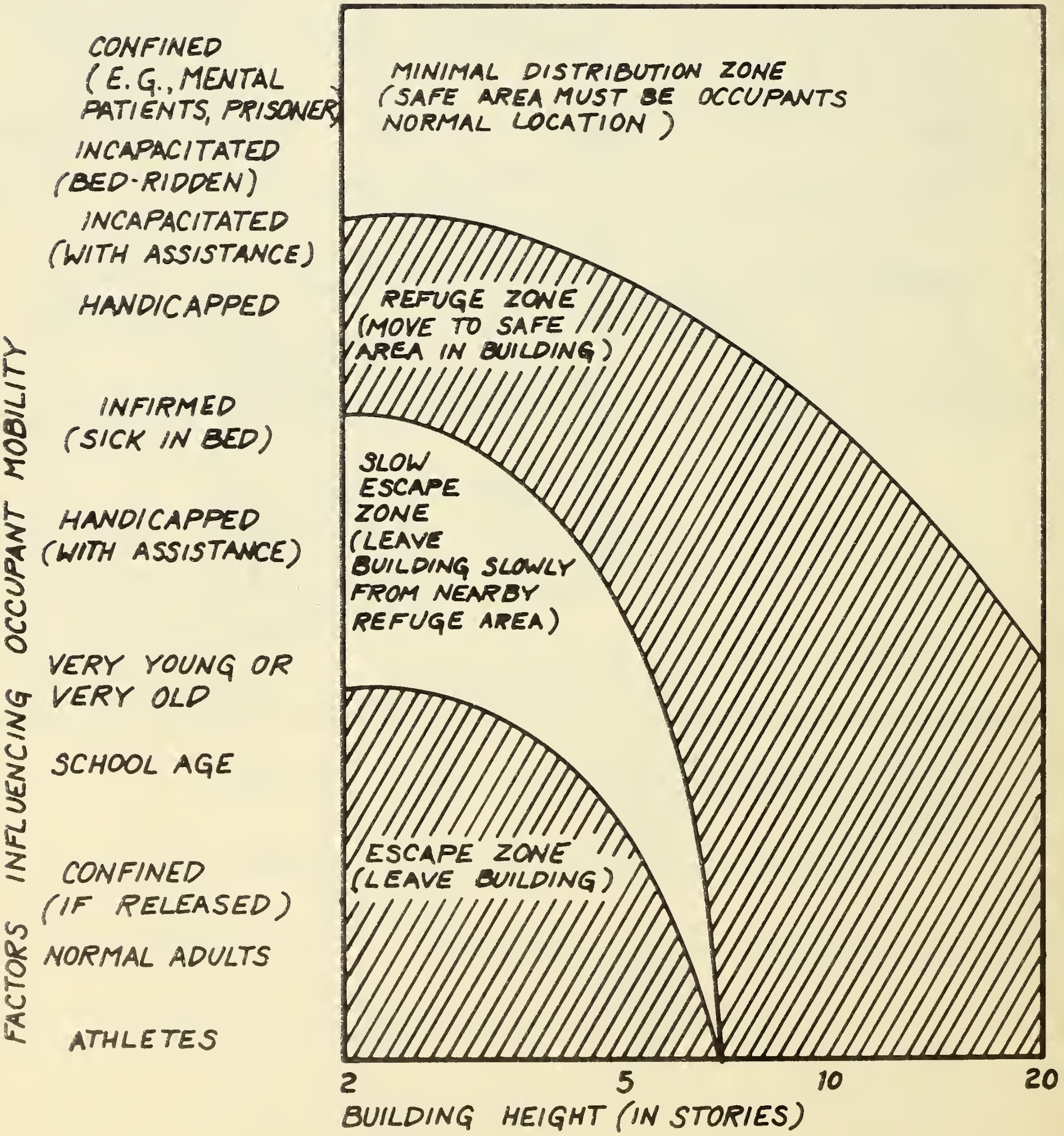


Figure 5-9

Figure 5-10



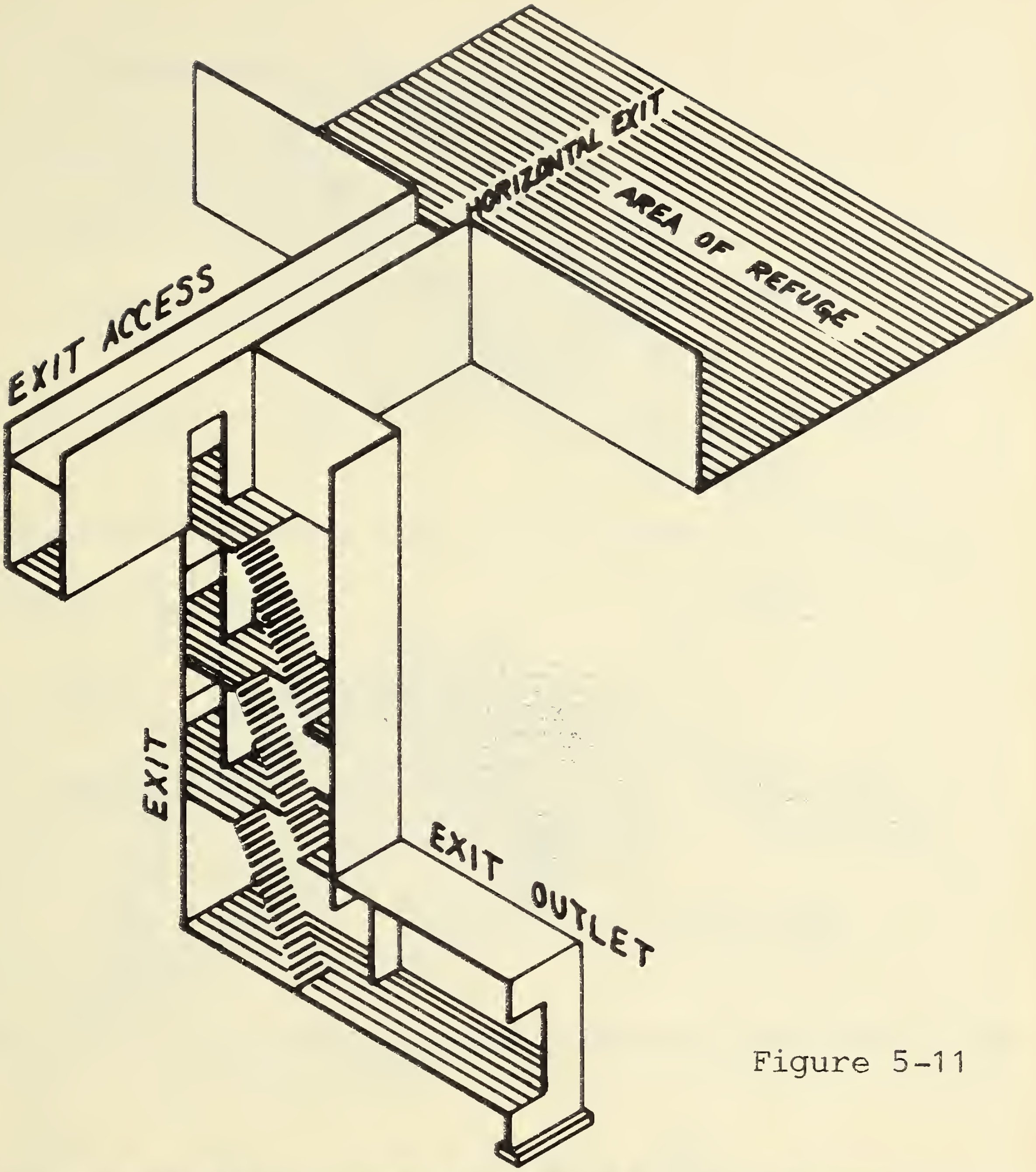


Figure 5-11

Figure 5-12

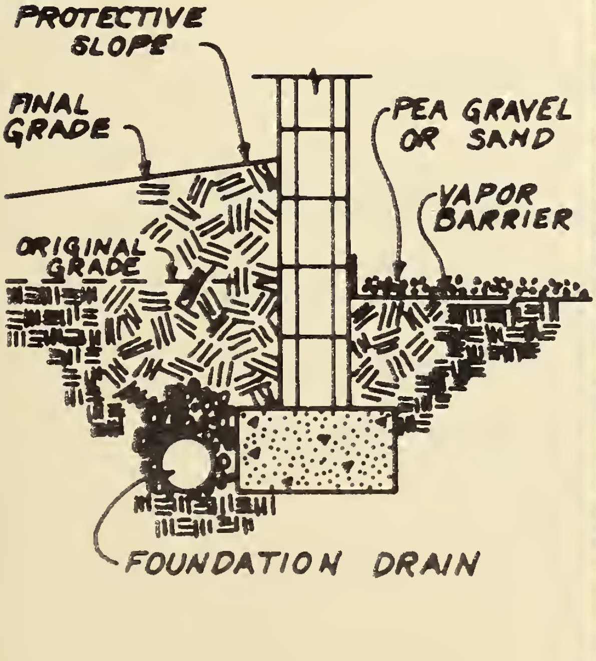
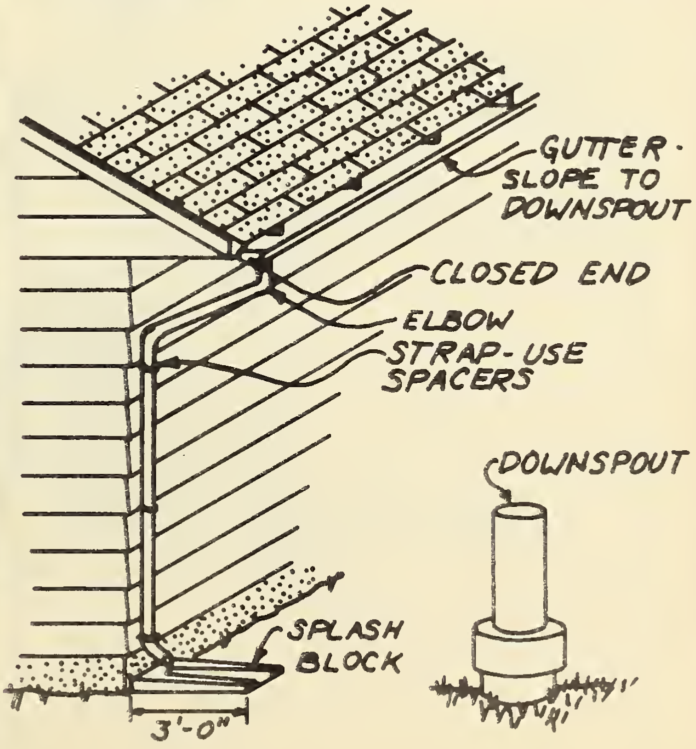


Figure 5-13



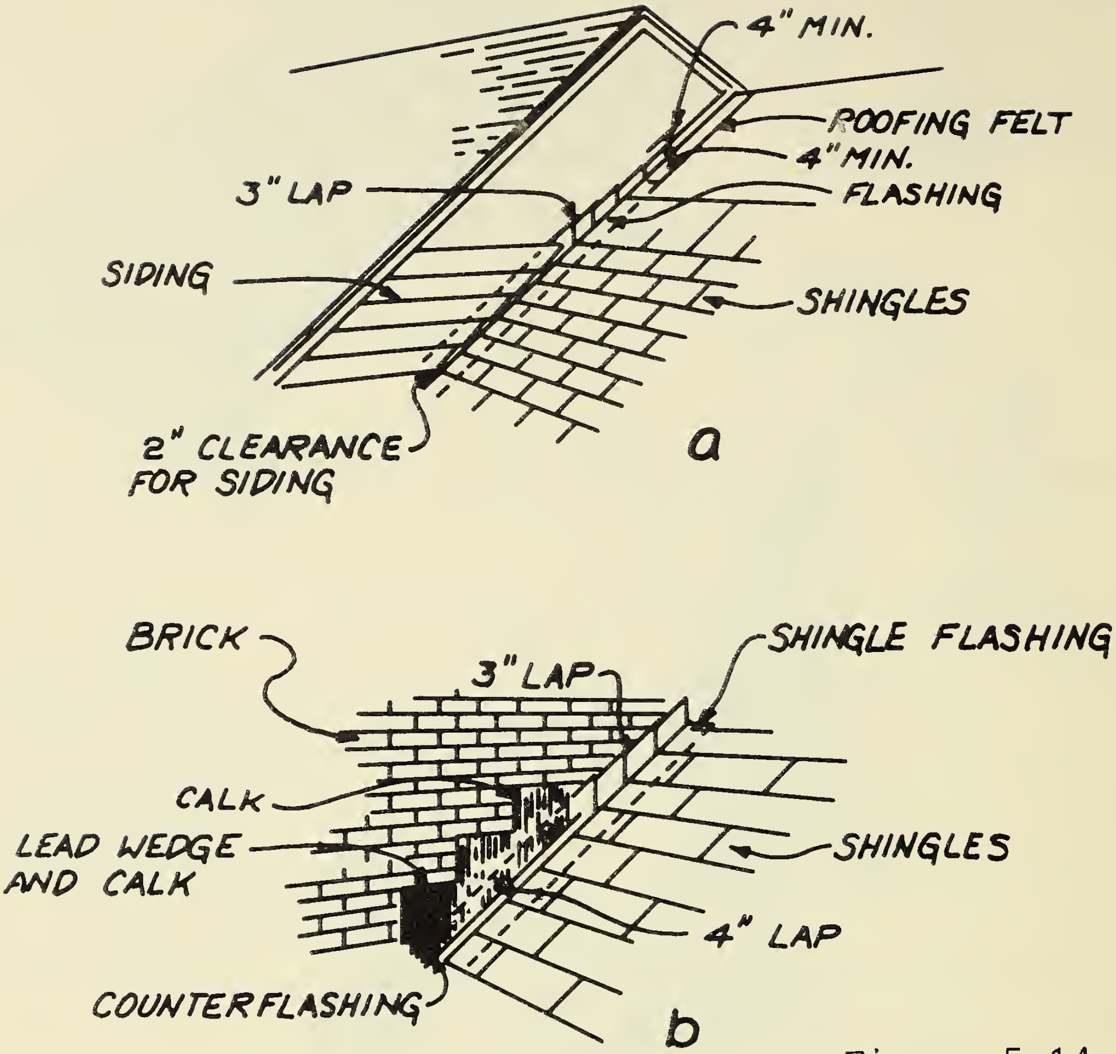


Figure 5-14

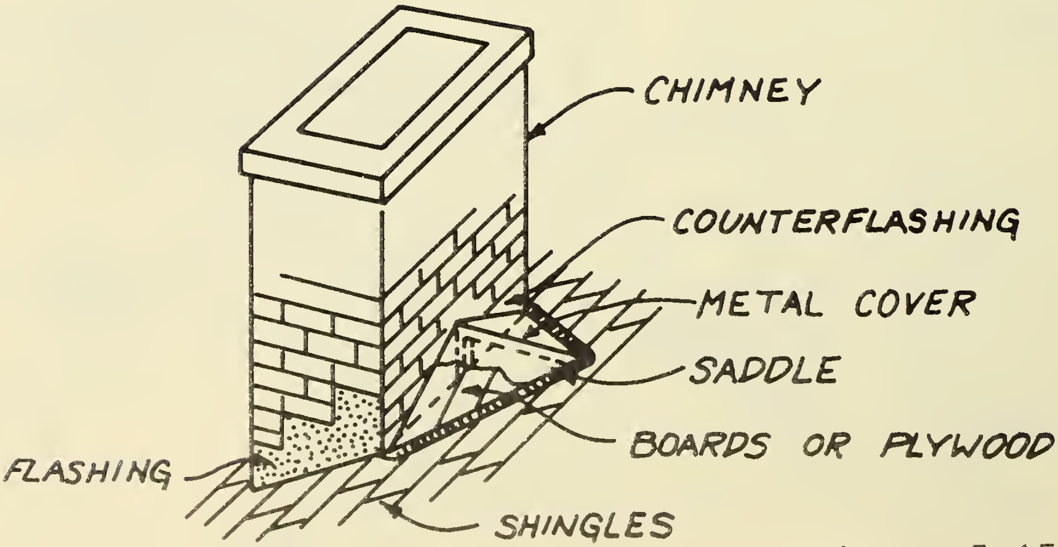


Figure 5-15

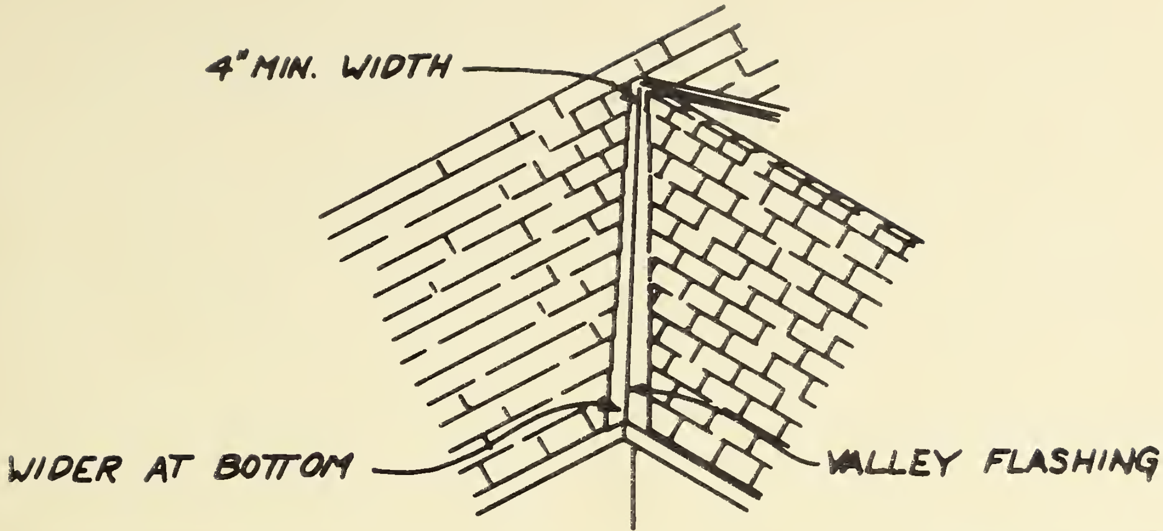


Figure 5-16

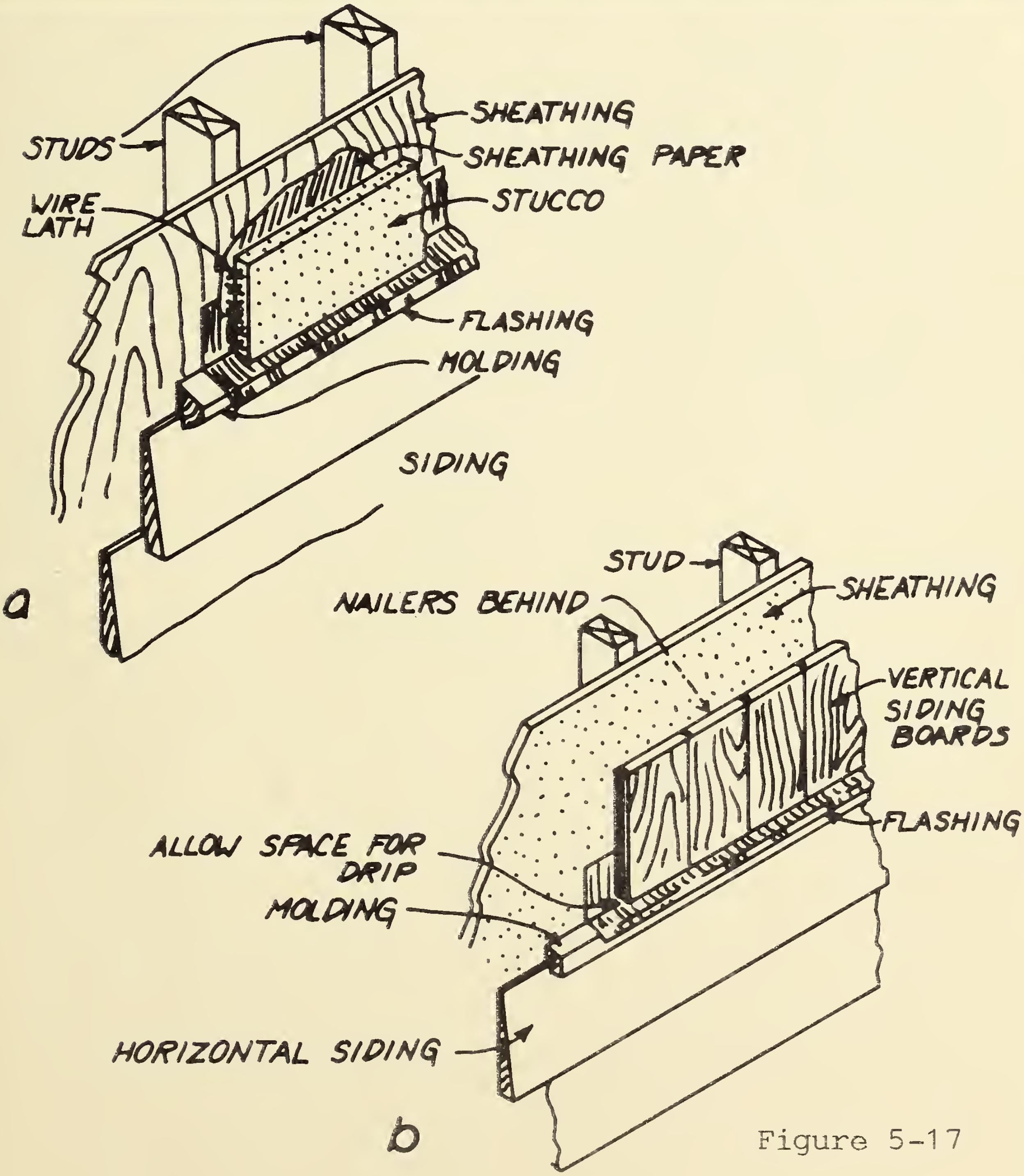


Figure 5-17

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